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Analysis of Rigid Pavement Reconstruction Using The 2024 Bina Marga MDPJ Method And Implementation Method on The Surabaya-Gempol STA Toll Road Section 10+200 – 11+400

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ABSTRACT

Rigid pavement is widely implemented on toll roads due to its high structural capacity to withstand heavy traffic loads and its long service life. This study aims to determine the required rigid pavement thickness for reconstruction based on the 2024 Bina Marga Pavement Design Manual (MDPJ) and to evaluate its construction implementation on the Surabaya–Gempol Toll Road, specifically between STA 10+200 and STA 11+400. A quantitative research approach was employed using literature review and secondary data analysis, including Average Daily Traffic (ADT), subgrade California Bearing Ratio (CBR), and geometric road characteristics. The pavement design analysis was carried out in accordance with the procedures specified in the 2024 MDPJ Bina Marga. The results indicate that the cumulative number of commercial vehicle axle groups (JSKN) over a 40-year design period reaches 41,791,131.23, while the equivalent subgrade CBR value is 20.04%. Based on these parameters, the proposed rigid pavement structure consists of a 300 mm Portland cement concrete slab, a 100 mm lean concrete base layer, a 200 mm Class A aggregate base course, and a 200 mm selected granular subbase layer. Structural performance evaluation shows a fatigue damage value of 0.00% and an erosion damage value of 82.51%, both satisfying the allowable design criteria. Therefore, the proposed pavement structure is considered structurally adequate, technically feasible, and capable of providing reliable long-term performance throughout its planned service life.

1. INTRODUCTION

Rigid pavement is widely used on toll roads because it has durability and a long service life, but premature damage is still common due to high traffic loads, subsoil conditions, and design inaccuracies. This study aims to analyse the thickness of rigid pavement using the 2024 Highway MDPJ method on the Surabaya-Gempol Toll Road section and review the implementation method. The results of this study are expected to be a reference in the planning and implementation of rigid pavement that is more effective and according to field conditions [1]. 1 Road Pavement Design Manual (MDP) Method 2024
Two things to consider in making a concrete thickness design
a. Melt Crack (Fatigue0)
The number of allowable load reps (Nf) for a given axis load value can be calculated using the following formula [4] :

$$log_{10} N_f = \frac{0,9719 - S_r}{0,0828}\ jika\ S_r > 0,55$$

$$N_f = \left(\frac{4,258}{S_r - 0,4325}\right)^{3,268}\ jika\ 0,45 \le S_r \le 0,55$$

$$S_r = \frac{S_e}{0,944\, f_{cf}}\left(\frac{P\, L_{SF}}{4,45\, F_1}\right)^{0,94}$$

$$S_e \text{ atau } F_3 = a + \frac{b}{D} + c\cdot\ln(E_f) + \frac{d}{D^2} + e\cdot[\ln(E_f)]^2 + f\cdot\frac{\ln(E_f)}{D} + \frac{g}{D^3} + h\cdot[\ln(E_f)]^3 + i\cdot\frac{[\ln(E_f)]^2}{D} + j\cdot\frac{\ln(E_f)}{D^2}$$

D	:	Concrete Slab Thickness (mm)
Ef	:	CBR Effective Base Soil (%)
Or	:	concrete equivalent stress (MPa)
Fcf	:	Strong bending design characteristics at concrete lifespan 28 days (MPa)
P	:	Axis group load (kN)
LSF	:	Load Safety Factor
F1	:	9 for single axle with single wheel (STRT)
	:	18 for single axle with double wheels (STRG)
	:	18 for tandem axle with single wheel (STdRT)
	:	36 for tandem axle with dual wheels (STdRG)
	:	54 for twin-wheel trideSSSm axis (STrRG)
	:	72 for four-axle with dual wheels (SQdRG)

Nf : infinite if the value of Sr is less than 0.45

The values of a, b, c, d, e, f, g, h, I and j are coefficients

b. Erosion damage

Erosion of the subsoil or bottom foundation layer arising from repeated deflection of joints and cracks. The amount of allowable load (Ne) can be calculated using the following formula:

$$log_{10}(F_2 N_e) = 14{,}524$$
$$-6{,}777\left[max\left(0\ atau\ \left(\frac{P\ L_{SF}}{4{,}45\ F_4}\right)^2 \frac{10^{F3}}{41{,}35} - 9{,}0\right)\right]^{0{,}103}$$

Description:

Ne : Total allowable load

F2 : Adjustment for effect on plate sides, 0.06 for plates with shoulders non-concrete as well as 0.94 for slabs with concrete shoulders

F3 : Factors Load Safety

F4 : Load adjustment for erosion due to axis groups,

: 9 for single axis with single wheel (STRT)

; 18 for single axle with double wheels (STRG)

; 18 for tandem axle with single wheel (STdRT)

; 36 for tandem axle with dual wheels (STdRG)

; 54 for twin-wheel tridem axis (STrRG)

; 54 for four-axle with dual wheels (SQdRG)

The values of a, b, c, d, e, f, g, h, I and j are coefficients

2. LITERATURE REVIEW

Rigid pavement is one of the most widely used pavement structures on toll roads due to its ability to withstand repetitive heavy traffic loads and its longer service life compared to flexible pavement. It distributes vehicle loads through the concrete slab to the underlying layers, reducing stress on the subgrade. Therefore, rigid pavement is commonly applied on road sections with high volumes of commercial vehicles, such as toll roads and major logistics routes. Its performance is influenced by several parameters, including slab thickness, concrete strength, subgrade condition, subbase quality, and cumulative traffic loading throughout the design life. Inadequate design of these parameters may lead to premature damage such as slab cracking, faulting, pumping, and reduced structural performance. Previous studies indicate that slab thickness is a key factor affecting the structural capacity of rigid pavement. [1] reported that increasing slab thickness significantly reduces tensile stress and slab deflection, thereby improving pavement service life [2] also found that the California Bearing Ratio (CBR) of the subgrade strongly affects pavement deformation. Lower CBR values tend to increase deflection and require adjustments in pavement design. In Indonesia, [3] showed that the Manual Desain Perkerasan Jalan (MDPJ) method provides pavement thickness designs that are more suitable for local traffic and material conditions than the AASHTO 1993 method. Furthermore, [4] stated that MDPJ 2024 offers a more comprehensive approach through fatigue and erosion evaluation. Based on these studies, the analysis of rigid pavement reconstruction thickness on the Surabaya–Gempol Toll Road using the MDPJ Bina Marga 2024 method is important to obtain a safe, effective, and appropriate pavement design for long-term traffic service.

3. METHODOLOGY

3.1 Research Stages

This research starts from the stage of reference literature study, secondary data collection (Length, road width and LHR) The steps of this research can be seen in the following research flow chart.

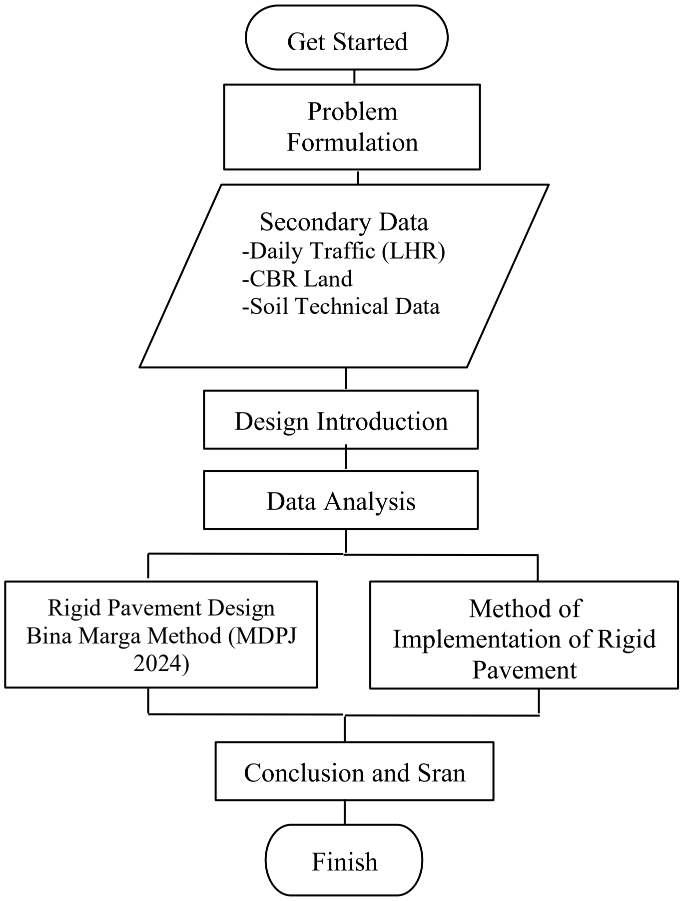

Figure 1. Research Flow Diagram

3.2 Research Location

This research was carried out on the Surabaya-Gempol Toll Road section, East Java Province, which is the place of the author's field work practice, This location was chosen because it has adequate traffic and geotechnical data for rigid pavement planning.

Figure 2. Research Location

4. RESULT AND DISCUSSION

The data analysis in this study uses the 2024 Road Pavement Design Method (MDPJ) as follows:

4.1 Plan Lifespan

The age of the plan with the type of rigid pavement obtained UR = 40 years. So the initial LHR of the planned life is 2025 and the final LHR for UR = 40 years is the LHR of 2064.

4.2 Traffic

a. Column Distribution Factor (DL)

Surabaya-Gempol toll road section. The Lane Distribution Factor (DL) with the standard load in the plan lane is 100%.

b. Traffic Growth Factors

The Surabaya–Gempol Toll Road section has a traffic growth factor of 4.83% which is used to calculate cumulative traffic growth over the planned lifetime. [4]

$$R = \frac{(1 + 0.01i)^{UR} - 1}{0.01i}$$

$$R = \frac{(1 + 0.01x\ 4{,}83\%)^{40} - 1}{0.01x\ 4.83\%}$$

$$R = 32.38$$

The multiplier factor of cumulative traffic growth in 2025 - 2064 is 32.38.

4.3 Number of Commercial Vehicle Axis Groups (JSKN)

Average Daily Traffic Data is converted to Number of Commercial Vehicle Axis Groups (JSKN) using Table 1. Vehicle Axis configuration, so that the results are obtained as shown in the table below [4]

Table 1. Number of Commercial Vehicle Axis Groups (JSKN)

Goal. Vehicles	LHR	JSKN	HVAG	STRT	STRG	STdRT	STdRG	STrRG	SQrRG
5B	1469	2	2938	1469	1469	0	0	0	0
6A	215		430	430	0	0	0	0	0
6B	150		300	150	150	0	0	0	0
7A1	180		360	0	180	180	0	0	0
7A2	115		230	115	0	0	115	0	0
7A3	101		202	0	0	101	101	0	0
7B1	115	1	115	115	0	0	0	0	0
7B2	120	4	480	0	360	120	0	0	0
7B3	113		452	113	226	0	113	0	0
7C1	110	3	330	110	110	0	110	0	0
7C2A	105		315	105	0	0	210	0	0
7C2B	100		300	100	100	0	0	100	0
7C3	105		315	105	0	0	105	105	0
7C4	102		306	102	0	0	102	0	102
Total	**3100**		**7073**	**2914**	**2595**	**401**	**856**	**205**	**102**
Proportion of Vehicle Type (%)			100.00	41.20	36.69	5.67	12.10	2.90	1.44

To calculate the daily average number of heavy vehicles on the design path cumulatively using the Equation:

JSKN : (ΣLHRJK×JSKNJK) ×365×DD×DL×R
JSKN : 7073×365×0.5×1×32.38
JSKN : 41.791.131,227
Description :
LHRJK : average daily traffic for each type of vehicle Nidagang (Vehicle Units Per Day)
JSKNJK : Total Axis of Commercial Vehicles of each type Commercial vehicles
DD : Directional distribution factors
DL : Column distribution factors
JSKN : Total Commercial Vehicle Axis Count over the life of the plan

4.4 Number of Commercial Vehicle Axis Groups (JSKN)

Based on Table 2, an equivalent CBR value of 20.04% was obtained which indicates that the subsoil meets the requirements for rigid pavement planning.

Table 2. CBR Ground Ground Design Equivalent

Material	CBR Bearing Capacity (%)	Thickness (m)	CBR^0.33	CBR^0,33*hi
(1)	(2)	(3)	(4) = (2) ^ 0.33	(5) = (3) (4)
LFA class A	83.88	0.2	4.31	0.86
Coarse-grained selection stack	30	0.2	3.07	0.61
Ground land	9	0.6	2.06	1.24
Total		**1**		**2.72**
CBR (%)				**20.04**

$$CBR\ Ekuivalen\ = \left(\frac{\Sigma_i h_i\, CBR_i^{\ 0.33}}{\Sigma_i h_i}\right) = 20{,}04\ \%$$

4.5 Thickness of the bottom foundation

Based on the JSKN value of 41,791,131.23, the minimum base thickness was obtained in the form of 100 mm thin concrete with an effective basic ground CBR of 75%

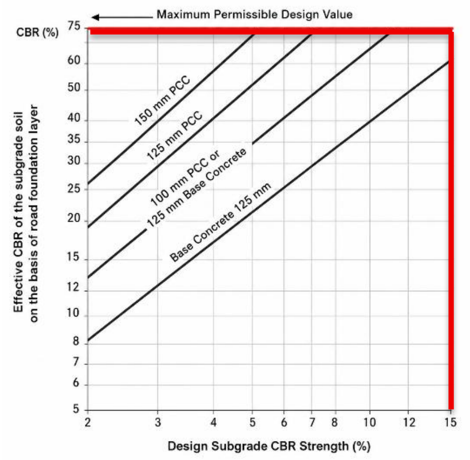

Figure 3. Basic Ground CBR Chart

4.6 Permissible Load Repetitions

The calculation of the permissible load reps according to the axis group is based on the JSKN load distribution plan. The results of the calculation of the permissible load reps can be seen in Table 3 to Table 7.

Table 3. Allowable load reps calculation results – STRT

Axis Load	Load Proportions	Proportion of Axis Group	Traffic Design	Permissible Load Reps
(kN)	(%100)	(%100)	(JSKN)	
90	0.012	0.4120	41791131.23	206609.9642
130	0		41791131.23	0

Table 4. Allowable load reps calculation results – STRG

Axis Load	Load Proportions	Proportion of Axis Group	Traffic Design	Permissible Load Reps
(kN)	(%100)	(%100)	(JSKN)	
90	0.0252	0.3669	41791131.23	386383.3219
130	0.1211			185678.519
150	0.0282			432381.3364

Table 5. Allowable load reps calculation results – STdRT

Axis Load	Load Proportions	Proportion of Axis Group	Traffic Design	Permissible Load Reps
(kN)	(%100)	(%100)	(JSKN)	
90	0.125	0.0567	41791131.23	296165.7646
130	0.0625			148082.8823
150	0.0313			74159.0745

Table 6. Allowable load reps calculation results – STdRG

Axis Load	Load Proportions	Proportion of Axis Group	Traffic Design	Permissible Load Reps
(kN)	(%100)	(%100)	(JSKN)	
90	0,0169			85475.35993
130	0,0246			124419.7547
150	0,0148			74854.16136
240	0,0492			248839.5094
310	0,0436			220516.3132
320	0,0126	0.1210	41791131.23	63727.19143
330	0,007			35403.99524
340	0,0091			46025.19381
350	0,0084			42484.79428
360	0,0035			17701.99762
380	0,0007			3540.399524

Table 7. Allowable load reps calculation results –STrRG

Axis Load	Load Proportions	Proportion of Axis Group	Traffic Design	Permissible Load Reps
(kN)	(%100)	(%100)	(JSKN)	
90	0,0345			41788.17696
130	0,1034			125243.4057
150	0,0345			
240	0,0345			
310	0,0345			
320	0,0345			
330	0,0345	0.0290	41791131.23	41788.17696
340	0,0345			
350	0,0345			
360	0,0345			
380	0,0345			
400	0,5172			626459.2789
430	0,0345			41788.17696

3.7 Fatigue and Erosion Factors.

The results of the calculation of fatigue and erosion factors can be seen in Table 9 to Table 13

Table 9. Fatigue and erosion factor calculation results – STRT

Axis Load (kN)	LSF Load Reps (Plan Load) (kN)	Permissible Load Reps	Equivalence of Fatal Factors	0.44	Equivalence of erosion factors	1.46
			Fatigue Factor Analysis		Erosion Fault Analysis	
			Allowed reps	Fatigue (%)	Allowed reps	Damage (%)
10	11	3443.499403	UNLIMITED	0.00	UNLIMITED	0.00
Total			Fatigue (%)	0.00	Erosion (%)	0.00

Table 10. Fatigue and erosion factor calculation results STRG

Axis Load (kN)	LSF Load Reps (Plan Load) (kN)	Permissible Load Reps	Equivalence of Fatal Factors	0.66	Equivalence of erosion factors	2,06
			Fatigue Factor Analysis		Erosion Fault Analysis	
			Allowed reps	Fatigue (%)	Allowed reps	Damage (%)
140	154	734434.965			42157285.3	1.74
150	165	432381.3364	UNLIMITED	0.00	10710126.55	4.04
160	176	116528.3034			4596868.701	2.53
170	187	6133.068601			2441173.183	0.25
Total			Fatigue (%)	0,00	Erosion (%)	8.57

Table 11. Fatigue and erosion factor calculation results – STdRT

Axis Load (kN)	LSF Load Reps (Plan Load) (kN)	Permissible Load Reps	Equivalence of Fatal Factors	0.44	Equivalence of erosion factors	2.15
			Fatigue Factor Analysis		Erosion Fault Analysis	
			Allowed reps	Fatigue (%)	Allowed reps	Damage (%)
120	132	148082.8823			742400165	0.02
130	143	148082.8823	UNLIMITED	0.00	22999602.73	0.64
150	165	74159.90745			3140135.259	2.36
160	176	518408.5543			282477.01	18.35
Total			Fatigue (%)	0.00	Erosion (%)	21.38

Table 12. Fatigue and erosion factor calculation results – STdRG

Axis Load (kN)	LSF Load Reps (Plan Load) (kN)	Permissible Load Reps	Equivalence of Fatal Factors	0.56	Equivalence of erosion factors	2.15
			Fatigue Factor Analysis		Erosion Fault Analysis	
			Allowed reps	Fatigue (%)	Allowed reps	Damage (%)
240	264	248839.5094			742400165	0.03
250	275	248839.5094			63316381.88	0.39
260	286	245299.1099			22999602.73	1.07
270	297	380340.0631			11680797.72	3.26
280	308	390961.2617			6943370.678	5.63
290	319	426365.2569			4528014.021	9.42
300	330	355557.2665			3140135.259	11.32
310	341	220516.3132			2275582.224	9.69
320	352	63727.19143	UNLIMITED	0.00	2184634.978	2.92
330	363	35403.99524			2102954.43	1.68
340	374	46025.19381			2029232.48	2.27
350	385	42484.79428			1962391.548	2.16
360	396	17701.99762			1901536.615	0.93
370	407	10621.19857			1845918.639	0.58
380	418	3540.399524			1794906.343	0.20
390	429	3540.399524			1747964.243	0.20
Total			Fatigue (%)	0.00	Erosion (%)	51.75

Table 13. Fatigue and erosion factor calculation results – STrRG

Axis Load (kN)	LSF Load Reps (Plan Load) (kN)	Permissible Load Reps	Equivalence of Fatal Factors	0.44	Equivalence of erosion factors	2.17
			Fatigue Factor Analysis		Erosion Fault Analysis	
			Allowed reps	Fatigue (%)	Allowed reps	Damage (%)
380	418	41788.17696			211785704.4	0.02
400	440	626459.2789	UNLIMITED	0.00	89496909.88	0.70
430	473	41788.17696			41704161.44	0.10
Total			Fatigue (%)	0.00	Erosion (%)	0.82

Fatigue Damage = 0.00% < 100% ----> OK
Erosion Damage = 82.51% < 100% ----> OK

4.8 Road Pavement Design

a. Thick Concrete

Based on the results of the analysis of rigid pavement on the Surabaya-Gempol Toll Road section with a planned traffic of 41,791,131.23 JSKN and a planned age of 40 years, the required thickness of concrete slabs was obtained of 300 mm. A fatigue value of 0.00% and erosion of 82.51% indicate that the pavement design meets the technical requirements.

Table 14. Results of Concrete Thickness Calculation Analysis

Material				Thickness (mm)
Cement concrete	fs:	4.5	MPa	300
Thin Concrete Bottom Foundation Layer				100
LFA Class A	CBR:	83.88	%	200
Coarse-grained selection stack	CBR:	30	%	200
Ground land	CBR:	9	%	-

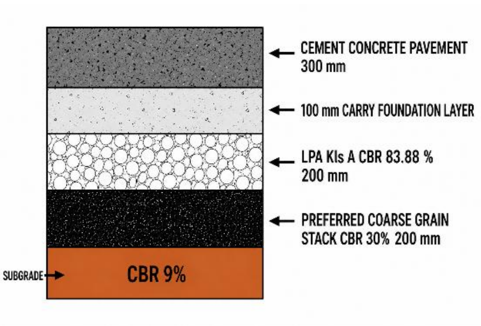

Figure 4: Calculation Results of Thick Layer of Rigid Pavement

4.9 Reinforcement Planning

Joint planning uses the type of cement concrete pavement connected with reinforcement (JRCP), as follows:
-Plate width: 4 x 5 m
-Plate length: 5 m
-Shrinkage connection distance: 5 m
-Dowel: Diameter 38, distance 300 mm, length of dowel 450 mm
-Tie rod (Tie bar): D16 - 687 mm, length Tie bar 700 mm

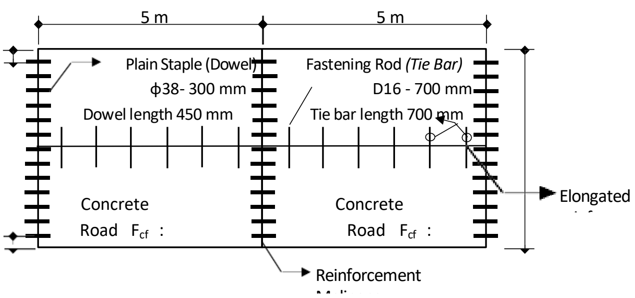

Figure 5. Rigid pavement Plan Drawings

4.9.1 Longitudinal reinforcement planning

Description:

Ace	:	Steel reinforcement cross-sectional area (mm2/m plate width)
Fs	:	Strong Pull Reinforcement (MPa). Usually, 0.6 times the melting stress
g	:	Acceleration of gravity (m/sec2)
h	:	Concrete slab thickness (m)
L	:	Distance between unfastened joints and/or plate-free edges (m)
M	:	Weight per unit volume of plates (kg/m3)
μ	:	The coefficient of friction between the concrete slab and the bottom foundation as in

$$A_s = \frac{L \times L \times M \times g \times h}{2 \times f_s}$$

As = 687.8 mm^2/m'
As min = 190 mm^2/m'
Used reinforcement 13 mm diameter, 300 mm distance

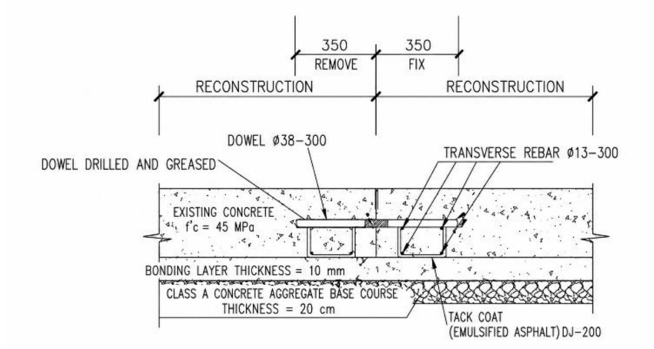

Figure 6. Dowel Detail Pictures

4.9.2 Transverse reinforcement planning

$$A_s = \frac{L \times L \times M \times g \times h}{2 \times f_s}$$

As = 335.502 mm2/m'
As min = 190 mm2/m'
Reinforced 13 mm diameter, 300 mm spacing is used.

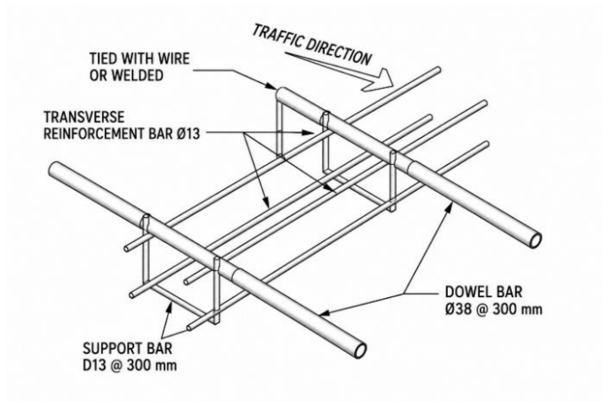

Figure 7. Dowel Detail Pictures

4.10 Rigid Pavement Construction Method

The rigid pavement construction method is a systematic sequence of construction activities carried out to produce pavement structures in accordance with the design specifications. The construction procedure on toll roads generally consists of the following stages [5].

4.10.1 Subgrade Preparation and Base Layer Construction

The initial stage includes site clearing, excavation, and grading of the subgrade to achieve the planned elevation. The subgrade is then compacted until it meets the required level of compaction specified in the design. Subsequently, the base layer is constructed by placing Lean Mix Concrete (LMC), which functions as a working platform and provides uniform support for the concrete slab above. [7].

4.10.2 Installation of Dowel Bars and Tie Bars

After the base layer has been completed, joint reinforcement installation is carried out using dowel bars and tie bars. Dowel bars are installed at transverse joints to transfer loads between adjacent concrete slabs. Tie bars are installed at longitudinal joints to maintain slab continuity and prevent separation between slabs. Installation is performed according to the specified position, spacing, and dimensions based on the applicable technical standards [7].

4.10.3 Concrete Placement (Rigid Pavement)

Concrete placement is generally performed using a concrete paver to ensure consistent pavement thickness and surface evenness. In specific conditions, such as narrow areas or complex geometries, concrete may be placed manually. The concrete mixture must meet the design requirements in terms of compressive strength and workability to ensure structural performance [7].

4.10.4 Compaction and Finishing

Following concrete placement, compaction is carried out using vibrators to eliminate air voids and ensure adequate concrete density. The concrete surface is then levelled and finished. Surface texturing is commonly applied to improve skid resistance and provide safer driving conditions for vehicles [7].

4.10.5 Concrete Curing

Concrete curing is performed immediately after finishing to maintain moisture content and prevent early-age cracking. The curing process may be carried out by spraying curing compound or by other methods such as wet covering, depending on field conditions and project requirements [8]

4.10.6 Joint Cutting

After the concrete reaches the required early-age strength, typically several hours after placement, contraction joints are cut using a concrete cutter. These joints function to control cracking caused by concrete shrinkage. After cutting, the joint openings are filled with sealant to prevent the infiltration of water and debris into the pavement structure [8]

5. CONCLUSION

Based on the results of the analysis of rigid pavement reconstruction thickness using the 2024 MDPJ Bina Marga method on the Surabaya–Gempol Toll Road section STA 10+200–11+400, it can be concluded that the equivalent subgrade CBR value obtained was 20.04%, indicating that the subgrade meets the requirements for rigid pavement design. The cumulative traffic loading during the 40-year design life reached 41,791,131.23 commercial vehicle axle groups (JSKN). Based on these parameters, the required pavement structure consists of a 300 mm cement concrete slab, a 100 mm lean concrete base layer, a 200 mm Class A base course, and a 200 mm selected granular subbase. The structural evaluation shows fatigue damage of 0.00% and erosion damage of 82.51%, both of which are below the allowable limit of 100%. Therefore, the rigid pavement design is declared safe and capable of supporting traffic loads optimally throughout its design service life. In addition, the construction implementation method consisting of subgrade preparation, base construction, dowel and tie bar installation, concrete placement, finishing, curing, and joint cutting can be applied effectively in accordance with technical standards to ensure pavement performance and durability.

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