Evaluation of Calculating Railroad Components on Maintenance Patterns at Level Crossings Using Concrete Level Crossings

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Abstract. The railway level crossing is a meeting point between a highway and a train. This analysis is conducted by identifying and evaluating the components of the Concrete Level Crossing feasible according to the dynamic loads by train and vehicle. Evaluation of Concrete Level Crossing is by observing the condition of the crossing, calculating the passing tonnage of the railroad and highway, calculating the rail tension based on the required railroad class and calculating sleeper tension. Based on the results of calculation, JPL 67 is a class II train line, with a passing tonnage of 12,7 million tons/year. The allowable tension of the rail does not appropriate the requirements of 1141 > 1128 kg/cm2. The rubber rail placement for rotation and stability does not fulfill with 5,701 > 0,0154 MPa for rotation and 38,334 < 112 mm for stability. Result from calculations of lifespan of concrete slab is found that the estimated service is according to the planned life of 10 years, but due to the results of the calculation of the thickness of the concrete plate due to the overload of passing vehicles thicker than the design thickness of the concrete slab is 27%, is estimated that the service life of the concrete level crossing is less than 10 years. The sleepers overstepping the boundaries the requirements for effective prestressing tension calculations with 4924,878 < 200 kg/cm^2. The maintenance pattern of Concrete Level Cross components is expected to be a reference for effective maintenance cycles at crossings.

Keywords: Level Crossing, Concrete Level Crossing, Passing Tonnage, Average Daily Traffic, Inspection, Maintenance

1 Introduction

The development of transportation development in Indonesia is increasingly massive in line with Law Number 23 Year 2007 states that transportation can support economic growth and regional development of the Unitary State of the Republic of Indonesia towards an advanced and independent country. Railways is one of the national modes of transportation that has the characteristics of mass transportation and is a unified system consisting of infrastructure, facilities, and human resources and has technical requirements to the procedures for implementing rail transportation. The operation has its own road track and is often crossed with a highway at a level crossing.

A. Pradipta et al. (eds.), *Proceedings of the 2nd International Conference on Railway and Transportation 2023 (ICORT 2023)*, Advances in Engineering Research 231,
https://doi.org/10.2991/978-94-6463-384-9_20

This crossing has a rule that railroads (trains) have priority over highways (motorized vehicles).

Railroad level crossing is the most prone point for accidents because at that point it becomes a crossing place between the highway and the train. Accidents that occur between trains and highway vehicles often occur at level crossings even though the crossing is equipped with infrastructure and supporting facilities that have been determined. One solution to the problem is the use of Concrete Level Crossing at level crossings because the location of the level crossing is passed by heavy vehicles. JPL 67 Krian is one of the level crossings that has used concrete level crossing as an alternative pavement at the crossing. JPL 67 is also passed by many heavy vehicles and is adjacent to various centers of human activity, such as government offices, schools, and so on. Therefore, the author argues that it is necessary to evaluate the use of pavement at the level crossing. Effectiveness in terms of durability and maintenance patterns of concrete level crossing railroad components at JPL 67 are important parameters in this study.

2 Methodology

2.1 Railway Components

Railroad components are a single unit of construction made of steel, concrete or other construction located on the surface, underground, and over the ground. The components of the railway structure must have been regulated in the Minister of Transportation Regulation Number 60 of 2012 regarding railway technical requirements [1]. The components of the railroad structure are rail, fastener, sleeper, and ballast.

2.2 Concrete Level Crossing

Concrete level crossing (CLC) is a concrete road slab as a substitute for surface pavement at level crossings usually by asphalt that can be quickly damaged when exposed to extreme weather and vehicle overloads[2] and quickly damaged when exposed to extreme weather and vehicle overload. Concrete level crossing is a breakthrough in the field of level crossing construction which is expected to be able to replace flexible pavement (asphalt) and rail block pairs that are commonly used as pavement at level crossings[3].

2.3 Passing Tonnage

Passing tonnage capacity is a value that reflects the type and amount of total load and speed of trains that pass within one year (tons/year). The calculation of carrying capacity is based on the frequency of trains passing through the railroad, the train set or arrangement of trains passing through, the type of train, the maximum speed of the train, and the maximum axle load pressure of the train. According to PT KAI calculations in the stages of calculating the traffic load that passes through the railway, the initial stage is to calculate the traffic load based on the arrangement of locomotives and railroad cars (trainset). The calculation can be done with the equation:

Weight of each train = Amount of train set x Train Set weight 1

T = 360 x S x TE 2

TE = Tp + (Kb x Tb) + (K1 x T1) 3

2.4 Daily Traffic Volumes

Daily traffic volume or used to see the traffic flow on the road. The daily traffic volume is obtained using a Traffic Counting survey in accordance with the provisions set out in the Indonesian Road Capacity Manual.

The daily traffic volume growth method is used to calculate the estimated traffic volume in 24 hours. The unrecorded traffic volume will be compared with the percentage growth of traffic volume at previous research by (Putra, 2019)[4] locations adjacent to this research location using the formula:

$$\frac{Night\ Volumes - Daytime\ Volumes}{Daytime\ Volumes}\ \% \quad 4$$

Determining the load of overloaded vehicles can be known by collecting weighing data based on the Total Permit Weight (JBI) obtained from the weighbridge and processed using the formula:

$$\frac{Weighing\ Result - JBI}{JBI}\ x\ 100\% \quad 5$$

The heaviest vehicle loads that passes can be calculated by summing up all types of vehicles that pass at a certain time with the formula:

$$V = s\ x\ t \quad 6$$

If the speed, distance, and travel time are known, you can calculate the heaviest load passing by using the formula:

$$\frac{Vehicle\ Volumes}{t} \quad 7$$

Furthermore, determining the traffic load on the highway is obtained from the accumulated load of each passing vehicle based on the average daily traffic calculation using the formula:

Passing Tonnage = Vehicle Count x Vehicle Weight x 360 8

2.5 Lifespan of Concrete Level Crossing

The calculation of the remaining life of the plan is the concept of damage caused by the number of repetitions of traffic loads in units of Equivalent Standard Load (ESAL) units that are expected to pass within a certain period of time.

The first stage to determine the life of the plan is to find out the Vehicle Damage Factor (VDF) for each vehicle using the formula:

$$E = k\ \left[\frac{L}{8{,}16}\right]^4 \quad 9$$

Traffic design (ESAL) is determined by using the formula:

$$W_{18} = \sum_{Ni}^{Nn}\ LHR_j x\ VDF_j\ x\ D_D x\ D_L x\ 365 \quad 10$$

The directional distribution factor (DD) set by AASHTO (1993) ranges from 0.3-0.7 and is generally taken as the middle value of 0.5. Meanwhile, the value of the lane distribution (DL) refers to Table 1 below.

Table 1. Lane Distribution

Number of Lanes in Each Direction	(DL)%
1	100
2	80 – 100
3	60 – 80
4	50 – 75

Then able to calculate the age percentage by using the formula:

$$Rl = 100\ [1 - \left[\frac{Np}{N1,5}\right]] \quad 11$$

After the ESAL value has been calculated, the ideal concrete slab thickness can be determined in accordance with the traffic traveled using the modified AASHTO (1993) formula:

$$Log_{10}W_{18} = 0{,}759 + 7{,}35Log_{10}(D+1) - \frac{0{,}1761(D+1)^{8{,}46}}{(D+1)^{8{,}46}+1{,}624x10^{7}} + 3{,}42Log_{10}\frac{D^{0{,}75}-1{,}132}{D^{0{,}75}-1{,}4631} \quad 12$$

2.6 Calculation of Moments on Concrete Level Crossing

Workload calculations can be divided into two, live load which is a non-fixed load and dead load (fixed load). As stipulated in SNI 1725: 2016 regarding loading on bridges, the result of this loading calculation is the amount of bending moment that has been multiplied by the load factor (Mu)[5] .

a. Dead Load
The self weight of concrete slab for a maximum width of 6 m is 2110 kg. The ultimate limit state load factor ϒu MS is 1.2 according to SNI 1725: 2016. Load factor for special (supervised) and ultimate limit state ϒu MA = 1.4

b. Life Load
Consisting of BTR load and BGT load. BTR is an evenly divided load, while BGT is centered line load. The load is then divided with an intensity of q kPa, the value of q depends on the total length L as follows:
If $L \leq 30$ m: q = 9 kPa

c. Heaviest vehicle weight
The heaviest load is obtained from the calculation of the load of vehicles passing at one time. With a Dynamic Load Factor is 30%

The structural modeling of the CLC concrete slab is a simple joint-roller superstructure. The magnitude of the factored bending moment (Mu) due to uniform load (qu) for simple supports and the moment due to centered load (Pu) with L is the length of the span [6].

$$Mu = \frac{1}{8} . qu . L^2 \quad 13$$

$$Mu = \frac{1}{4} . Pu . L \quad 14$$

2.7 Rubber Rail Calculation

The design of rubber rail on concrete level crossing is based on SNI 3967: 2008 [7] concerning planning the use of elastomeric bearings on bridges using the formula:

a. Form Factors

Calculation of the form factor to determine the normative reference for further calculations to support the load that will be received.

$$Ip = 2(L+W) \quad 15$$

$$S = \frac{A}{lp . hri} \quad 16$$

b. Permit Tension

This calculation is used to obtain the permit tension value according to the technical provisions listed in SNI 3967: 2008 where the evaluation result value is <7.0 MPa.

$$\sigma_S = \frac{P_{DL}+P_{LL}}{A} \quad 17$$

c. Shear Deformations

Calculations are carried out to obtain the value of the movement acting on the rubber rail so as to determine the shear limitations acting on the rubber rail.

$$h_{rt} \geq 2\ \Delta_S \quad 18$$

d. Rotation

The calculation is to achieve the required tolerance rotation value and the rotation value must be ≤ σ_S.

$$\sigma_S \geq 0{,}5\ G.S\ (\frac{L}{h_{ri}})^2 \frac{\theta+x}{n} \quad 19$$

e. Stability

The calculation is carried out to obtain the stability value at the thickness of the rubber rail where the value according to the technical requirements must $H \leq \frac{L}{3}$ or $H \leq \frac{W}{3}$.

2.8 Allowable Tension and Tension at the Base of the Rail

The calculation of rail dimensions should be based on the bending stress that occurs at the base of the rail due to the dynamic load of the vehicle wheels (Sbase). This stress must be less than the allowable stress value of the rail profile. The allowable stress is influenced by the quality of the rail.

The initial step to determine the dimensions of the rail is to calculate the passing tonnage and also the plan speed. After passing tonnage is known, the next step is to know the static and dynamic loads. After that, calculate the maximum moment with the formula:

$Ma = 0{,}82\frac{Pd}{4\gamma}$, for locomotive CC 20

Where to find the value of Pd and γ with the formula:

$Pd = Ps[1 + 0{,}01\left(\frac{V\,plan}{1{,}069} - 5\right)$ 21

$\gamma = \sqrt[4]{\frac{K}{4El}}$ 22

$Sbase = \frac{Ma}{Wb}$ 23

2.9 Moment on Sleepers

Calculations on concrete sleepers are carried out to determine the durability of concrete sleepers due to the train load that passes through them. The following is the calculation of stress in concrete sleepers:

a. Analysis of Modulus of Elasticity value based on fcu value (Concrete Quality).

$E = 6400\sqrt{fcu}$ 24

b. Analysis of the calculation of the damping factor in the sleeper section under the rail and the center of the sleeper.

$\gamma_r = \sqrt[4]{\frac{K}{4Elx}}$ 25

c. Calculation analysis of the load received by the sleeper from the train

Q = 60% PD 26

d. Calculation analysis of moment values at points c and d (just below the foot of the rail), e and f (under the support plate S1), g and h (under the support plate S2) and O (in the middle of the sleeper).

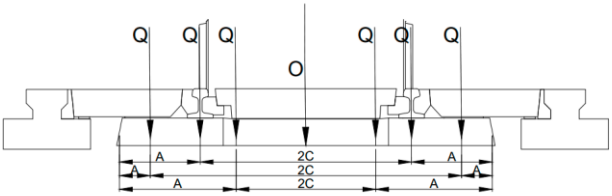


Fig. 1. Moment to Sleeper

1. Moment at the bottom of the rail (Mcd)

$\frac{Q}{4\gamma}\frac{1}{Sin\,\gamma L + Sinh\,\gamma L}[\,2cosh^2\gamma a - 2cos^2\gamma a\,(cosh2\gamma c cos\gamma L) - sin2\gamma a\,(sin2\gamma c + sin\gamma L) - sin2\gamma a\,(sinh2\gamma c + sin\gamma L)]$ (27)

2. Moment at the center of the sleeper (Mo)

$$\frac{Q}{2\,\gamma}\frac{1}{Sin\,\gamma L + Sinh\,\gamma L}\left[sinh\,sinh\,\gamma c\,\left(sin\gamma c + sin\gamma(L-c)\right) - sin\gamma c\; cosh\,sinh\,\gamma\,(L-C) - cos\gamma c\,cosh\,cosh\,\gamma\,(L-C)\right]$$ (28)

e. Initial Prestressed Stage Stress Analysis

$$P_{initial} = \sigma broke\ x\ A_{prestress\ steel} \quad (29)$$

1. *Top side of the bottom of the rail*

$$\sigma = \frac{P_{initial}}{A1} - \frac{P_{initial} \cdot e}{W1a} \quad e = 0{,}135 \quad (30)$$

2. *Bottom side of the bottom of the rail*

$$\sigma = \frac{P_{initial}}{A1} - \frac{P_{initial} \cdot e}{W1b} \quad e = 0{,}135 \quad (31)$$

3. *Top side of the center of the sleeper*

$$\sigma = \frac{P_{initial}}{A2} - \frac{P_{initial} \cdot e}{W2a} \quad e = 1{,}055 \quad (32)$$

4. *Bottom side of the center of the sleeper*

$$\sigma = \frac{P_{initial}}{A2} - \frac{P_{initial} \cdot e}{W2b} \quad e = 1{,}055 \quad (33)$$

f. Tension analysis of effective prestressing stage

P effective = P intial.(1-R) (34)

R = load reduction due to prestress loss

R = 25 %

1. *Top side of the bottom of the rail*

$$\sigma = \frac{P_{efektif}}{A1} - \frac{P_{efektif}\ .\ e}{W1a} + \frac{M}{W1a} \quad e = 0{,}135 \quad (35)$$

2. *Bottom side of the bottom of the rail*

$$\sigma = \frac{P_{efektif}}{A1} - \frac{P_{efektif}\ .\ e}{W1b} + \frac{M}{W1b} \quad e = 0{,}135 \quad (36)$$

3. *Top side of the center of the sleeper*

$$\sigma = \frac{P_{efektif}}{A2} - \frac{P_{efektif}\ .\ e}{W2a} + \frac{M}{W2a} \quad e = 1{,}005 \quad (37)$$

4. *Bottom side of the center of the sleeper*

$$\sigma = \frac{P_{efektif}}{A2} - \frac{P_{efektif}\ .\ e}{W2a} + \frac{M}{W2a} \quad e = 1{,}005 \quad (38)$$

2.10 Component Sacking Cycle

After calculations on rail and sleeper stresses and identification in the field, the next step is to calculate the need for Sacking.

Based on calculations from the Guidelines for Railways and Bridges (Perjana) 2C, this sacking cycle can be known after the results of the calculation of passing tonnage or annual cross-carrying capacity at JPL 67 Krian

$$F = 0{,}023\ x\ T^{0{,}30} x\ v\ maks\ x\ (1 + Fp) \quad (39)$$

Which is,

(Fp) = Jb + Jp +Js +Kf (40)

2.11 Method of Analysis

Method In this data analysis, the calculation method is used according to the provisions of the technical specifications of Ministerial Regulation 36 of 2011 and Decree of the Director General of Land Transportation No. 770 of 2005. Several stages are carried out to analysis the data is :

a. The results of Gapeka and Train Set data processing were analyzed to obtain the annual traffic load.

b. The results of the calculation of daily traffic volume are used to see the condition of the road section passing through the level crossing. The results of processing vehicle weight data are analysis for the percentage of vehicle overloads to determine the cross-road load that passes through the crossing.

c. The results of data processing of material specifications of concrete level crossing components, rail specifications, sleeper specifications are analyzed to evaluate and calculate the working moments according to applicable regulations. And the results of fastening and ballast specification data are processed to determine the condition of the components based on the results of laboratory testing.

d. Recommend maintenance cycle of railroad components at Concrete Level *Crossing* based on Minister of Transportation Regulation No. 32 Year 2011.

3 Results and Analysis

3.1 Annual Passing Tonnage Calculation

The frequency of trains passing through JPL 67 Krian is 56 trains per day with the following details:

Passenger Trains : 44 trains/day
freight Train : 6 trains/day
KRD : 6 trains/day

The load of the passing facilities has a total locomotive weight of 4852 tons/day (TI), a total passenger train weight of 18702 tons/day (Tp), and a total freight train weight of 4328 tons/day (Tb). Based on the Minister of Transportation Regulation No. 60 of 2012, the maximum axle load for a width of 1067 mm is 18 tons. then the Kb value used is 1.5 and the KI value is 1.4. Calculation of passing tonnage using the equation (2) and (3).

TE = Tp + (KbxTbl) + (K1xTl)
TE = 18702 + (1,5 x 4328) + (1,4 x 4852)
TE = 31986,8
T = 360 x S x TE , S= 1,1 with maximum velocity 120 km/h.
T = 360 x 1,1 x 31986,8
T = 12,26 Million tons/year.

The result of the calculation of passing tonnage passing at 67 Krian is 12.6 million tons/year.

3.2 Daily Traffic Volume

The vehicle weight data from two sources, for light vehicles can be known from Bina Marga regulations (1987) and heavy vehicles obtained from the results of weighing vehicles at the Trosobo weighbridge, Sidoarjo which can be seen in Table 2.

Table 2. Weight of each Vehicle

Vehicle Type	Class	Weight (Tons)
Sedan, jeep	2	2,00
Pickup	3	2,10
Truck 2 as, micro truck	4	8,30
Light Bus	5a	8,30
Heavy Bus	5b	9,00
Truck 2 as (H)	6	15,15
Truck 3 as	7a	25,00
Truck 4 as, truck	7b	31,40
Truck S, trailer	7c	40,13

After calculating the weight of each type of vehicle, we can then determine the heaviest load that crosses the concrete level crossing at one time using the equation (6).

t = 1 s, for light vehicle

t = 2 s, for heavy vehicle

Then the results are calculated using the equation (7) to determine the heaviest weight passing in the peak hour, for example on trucks with 2-axle (2D).

Accumulated weighted loads of all vehicle types = 9,43 ton

Annual traffic load

Calculation of annual traffic load using accumulated traffic load

T = 491483,96 tons x 360

T = 176934226 tons/year

3.3 Lifespan of Concrete Level Crossing

Table 3. Axis Load Sharing Due Overloading According to Bina Marga (1987)

Vehicle	Weight (ton)	Load configuration wheel axis (tons)				
		Front	B1	B2	B3	B4
Car	2,00	1,00	1,00			
Pickup	2,58	1,23	1,35			
Truck 2 as, micro truck	9,21	3,13	6,08			
Light Bus	8,3	2,82	5,48			
Large Bus	9,0	3,06	5,94			
Truck 2 as (H)	18,78	6,38	12,40			
Truck 3 as	29,50	7,37	11,06	11,06		
Truck 4 as	38,30	6,89	10,72	10,34	10,34	
Truck S, trailer	40,13	5,88	10,00	10,10	7,00	7,25

The results of the recapitulation of the cumulative VDF calculation due to actual overloading based on Bina Marga (1987) can be seen in Table 6.

Table 4. Cumulative Overload VDF

Vehicle	*VDF due to overloading*	*Cumulative VDF due to overloading*
Class 2	0,0005	1627,149
Class 3	0,0013	3572,059
Class 4	0,3303	315799,231
Class 5a	0,2174	3155,561
Class 5b	0,3006	4363,209
Class 6	5,7075	5457495,041
Class 7a	5,3145	5915020,037
Class 7b	8,6576	4546763,636
Class 7c	4,1718	17587354,707
Total		33835150,632

Before calculating the percentage of the plan life, first calculate the cumulative ESAL at the end of the plan life using Equation (10) with a plan life of 10 years and the DD value is used 0,5 as recommended by AASHTO (1993) which is between 0,3-0,7 and the DL value is used 1 according to the number of lanes of each lane so that the calculation is :

$= 33835150{,}632\ x\ D_D\ x\ D_L\ x\ \left[\frac{(1+0{,}1483)^{20}-1}{0{,}1483}\right]$

$= 340650163{,}382\ ESAL$

The results of the recapitulation of the calculation of the plan life can be seen in Table 5 below.

Table 5. Percentage Decrease in Lifespan

Year to-	Np (ESAL)	N1,5 (ESAL)	R*l* (%)
1	16917575, 31	340650163,38	95,03
2	36344027, 05	340650163,38	89,33
3	58651421, 57	340650163,38	82,78
4	84267002, 71	340650163,38	75,26
5	113681374,53	340650163,38	66,62
6	147457897,69	340650163,38	56,71
7	186243479,23	340650163,38	45,32
8	230780962,52	340650163,38	32,25
9	281923354,58	340650163,38	17,24
10	340650163,38	340650163,38	0,00

As a result, it can be seen that the planned age of the concrete level crossing plate can reach the planned age of 10 years, then the ideal concrete plate thickness can be known to reach the planned age, namely with equation (12)

$= 0{,}759 + 7{,}35Log_{10}(D+1) - \frac{0{,}1761(D+1)^{8{,}46}}{(D+1)^{8{,}46}+1{,}624x10^{7}} + 3{,}42Log_{10}\frac{D^{0{,}75}-1{,}132}{D^{0{,}75}-1{,}4631}$

Based on the results of these calculations, the value of D = 9.3 inches or 2108 mm ~ 21 cm is obtained. Based on the design thickness of the concrete level crossing plate of 16 cm, it can be obtained a decrease in the need for a concrete plate thickness of 5 cm, or a decrease of 27% from the ideal thickness required at JPL 67 Krian.

3.4 Calculation of Concrete Level Crossing

Calculations on CLC components are carried out to identify components based on the loading and technical provisions listed in SNI 1725: 2016 for concrete slabs and SNI 3967: 2008 for Rubber Rail.

3.4.1 Moments on Concrete Slab

- Service Moment = 47,457

M_D = 1/8 x qD x L2 kNm

= 39,548 $M_{BTR}ult$ = M_{BTR} x

M_{BTR} = 1/8 x q x L2 1,8

= 2,733 kNm = 4.920

M_{BGT} = 1/4 x q x L kNm

= 9,922 kNm M_{BGT}ult = M_{BGT} x 1,8

M_T = 1/4 x P x L = 17,860

= 6,239 kNm kNm

M_Tult = M_T x 1,8

- Ultimate Moment = 11,231

$M_{D\,ult}$ = M_D x 1,2 kNm

Ultimate Moment Combination = 81,471 kNm

Conversion to kg cm = 830772,995 kg

Table 6. Moment on CLC Concrete Slab

Slab	Moments (kg)
S1	830772,995 kg
S2	621884,129 kg

3.4.2 Placement on Rubber Rail

Calculation of rubber rail on concrete level crossing components includes shape factor using equation (15), allowable stress using equation (16), shear deformation using equation (17), rotation check using equation (18), and stability check using equation (19).

Tabel 7. Placement on Rubber Rail

Calculation	**Requirements**	**Result**	**Remarks**
Permissible tension	≤ 7,00 MPa	0,0154 MPa	Fulfill
Shear Deformation	≥ 20 mm	176 mm	Fulfill
Rotation	≤ 0,0184	L = 5,701 MPa	L = Doesn't Fulfill

Stability	MPa ≥ 112 mm	W = 0,0083 MPa L = 1000 mm W = 38,334 mm	W = Fulfill L = Fulfill W = Doesn't

3.5 Rail Permissible Tension Calculation

The rail component used in JPL 67 is R54 rail. Based on the railroad class classification and the passing tonnage value, the acceptable allowable stress value is not more than 1325 kg/cm^2 and the acceptable rail base stress value is not more than 1128.0 kg/cm^2.

Which is,

$$Pd = 7500\,[1 + 0{,}01\left(\frac{137{,}5}{1{,}069} - 5\right)] = 162772 \text{ kg}$$

$$\gamma = \sqrt[4]{\frac{180}{4\ x\ 2{,}1x10^6\ x\ 2346}} = 0{,}009977\ cm^{-1}$$

$$\text{Ma} = 351741{,}17 \text{ kg cm}$$

$$\sigma = 1142{,}36\ kg/cm^2 \ \leq 1325 \text{ kg}/cm^2$$

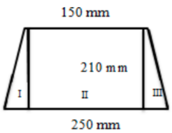
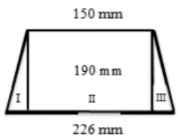
$$\text{Sbase} = 1141{,}896 \geq 1128 \text{ kg}/cm^2$$

Based on the Minister of Transportation Regulation No. 60 of 2012, the allowable stress value of the rail used has met the requirements and does not exceed 1325 kg/cm^2 with the calculation results of 1142,364 kg/cm^2. Meanwhile, the allowable stress value at the base of the rail does not meet 1141.896 kg/cm^2 exceeding the provisions of 1128 kg/cm^2.

3.6 Moments on Sleeper

The sleeper dimensions used at the JPL 67 crossing Mojokerto - Wonokromo are shown in Table 8.

Table 8. Sleeper Dimension

Item	Sleeper	
	Bottom of the Rail	Middle of Sleeper
Dimension		
Area (A)	A1 = (150+250)/2 x 210 = 420 cm2	A2 = (150+226)/2 x 190 = 357 cm2

Inertia (Ix)	Ix_1= 1/12.b. h^3+2(1/36.b.h) = 1/12x15x21^3+2(1/36x5x21^3) = 14148,75 cm^4	Ix_2= 1/12.b. h^3+2(1/36.b.h) = 1/12x15x21^3+2(1/36x5x19^3) = 10021,7611 cm^4
Ya	21-Y_{1-b}= 11,37 cm	21-Y_{2-b}= 11,207 cm
Yb	$Y_{1-b}=\frac{LuasI\frac{21}{3}+LuasII\frac{21}{3}+LuasIII\frac{21}{3}}{420cm^2}$ = 9,625 cm	$Y_{2-b}=\frac{LuasI\frac{21}{3}+LuasII\frac{21}{3}+LuasIII\frac{21}{3}}{357cm^2}$ = 9,793 cm
Wa	$W_{1a}=\frac{14148,75}{11,37}$ = 1243,85 cm^3	$W_{2a}=\frac{10021,7611}{10,135}$ = 894,2 cm^3
Wb	$W_{1b}=\frac{14148,75}{9,625}$ = 1470 cm^3	$W_{2b}=\frac{10021,7611}{8,865}$ = 1023,4 cm^3

Sleeper tension can be obtained by doing the following calculations:

a. Calculation of the elasticity modulus value based on the fcu value (concrete quality) with the equation (25).

E = $6400\sqrt{500}$

b. Calculation of the load received by the sleeper from the train using the equation (26).

Q = 60% PD (PD is load from rail and concrete slab)

c. Analysis of the calculation of the moment value at points c and d (just below the rail foot), e and f (under the support of Plate S1), g and h (under the support of Plate S2) with the equation (30) and (31).

Furthermore, the recapitulation calculation of effective prestressing tension can be known in table 1.

Table 9. Moment on Sleeper

Calculation Item	Requirements	Results	Remarks
	Initial Prestress Tension		
top side of the bottom of the rail (kg/cm^2)	< 200 kg/cm^2	81,080	Fulfill
bottom side of the bottom rail (kg/cm^2)	< 200 kg/cm^2	81,675	Fulfill
top side of the center of the sleeper (kg/cm^2)	< 200 kg/cm^2	57,777	Fulfill
bottom side of the center (kg/cm^2)	< 200 kg/cm^2	63,121	Fulfill
	Combination Effective Prestress Tension		
top side of the bottom of the rail (kg/cm^2)	< 200 kg/cm^2	2101,306	Doesn't fulfill
bottom side of the bottom rail (kg/cm^2)	< 200 kg/cm^2	1789,791	Doesn't fulfill
top side of the center of the sleeper (kg/cm^2)	< 200 kg/cm^2	846,220	Doesn't fulfill
bottom side of the center (kg/cm^2)	< 200 kg/cm^2	750,242	Doesn't fulfill

3.7 Fastener Check

The fastening system at level crossings used for Concrete Level Crossing is an elastic fastening type, namely E-Clip fastening. The fastening components used at the Concrete Level Crossing can be seen in Figure 2.

Fig. 2. Concrete level crossing fastener

The technical specifications of the clamping force attached to the concrete level crossing can be seen in Table 11.

Table 10. Specification of Concrete Level Crossing Fastener

Fastener Type	Requirement	Clamping Force	Description
E-Clip Fastener	900-1300 kgf	1050 kgf	Fulfill

3.8 Scouring Cycle Calculation

In addition, the calculation of the need for breaking based on passing tonnage is also needed to determine the need for breaking based on the formula in equation (2-40) the need for breaking is the frequency of breaking of the railroad in a year based on the annual passing tonnage or passing tonnage and the annual cross load of the roadway.

Due to all the determining factors obtained at 0%, and based on the Minister of Transportation Regulation No. 60 of 2012, the crossing is included in the category of rail road class II because the Passing tonnage on the Mojokerto - Wonokromo intersection is 12.6 Million tons / year, the maximum speed (S) of the crossing is 110 km / hour.

$F = 0{,}023\ x\ T^{0{,}3}\ x\ v\ maks\ x\ (1 + fp)$

$F = 0{,}023\ x\ (12{,}6 + 176{,}9)^{0{,}3}\ x\ 110^{0{,}5}\ x\ (1 + 0)$

F = 1,17/year

Based on the results of the calculation of the frequency of ballast breaking, it can be seen that referring to the load passing through the concrete level crossing, it is necessary to break it every 12 months.

3.9 Requirements Evaluation

Based on [8] that railway components that do not meet the requirements will have an impact on the service life and damage to the railroad components.

Known that the results of the calculation of the basic stress of the rail exceed the provisions which will have an impact on the rail will be more quickly damaged such as worn rails, cracked rails, to loose fastening. As for the evaluation results of the rubber rail component, it can be seen that the rotation check value exceeds the provisions, as well as for the width stability check value which is less than the provisions so that in these conditions the rubber rail will be more quickly damaged such as deformation and reduced elasticity in the rubber rail. The results of the calculation of the need for thick concrete plates due to traffic and excessive loads at JPL 67 found that the design thickness is less than the thickness required according to the need for thick concrete plates due to excessive loads passing at JPL 67 Krian so that the service life will be shorter than the planned life. For the results of sleeper calculations, it is known that the effective stage sleeper stress exceeds the provisions caused by the excessive load received by the sleeper, in these conditions the sleeper will experience faster damage such as cracked, broken, and broken sleepers. In the results of the visual inspection of the ballast rock, it was found that some rocks had an inappropriate shape and size, which could result in the ballast experiencing mud pumping and reduced elasticity of the ballast layer.

Due to periodic inspection and maintenance at the crossing cannot be done daily, the maintenance of railroad components at the concrete level crossing is carried out simultaneously every 12 months during the process of ballasting using MTT, based on [9] such as required maintenance on concrete level crossing components in the form of epoxy concrete coating and inject grouting on concrete slabs in the event of fine cracks, replacement of inelastic rubber, monthly maintenance on railroad components in the form of grinding and straightness maintenance on rail components, visual observation of sleepers, tightening loose fastenings and replacing loose and missing fastenings.

4 Conclusions and Suggestions

4.1 Conclusions

Based on the results of calculations and observations of conditions in the field, it can be seen that there are 3 calculations that do not meet the requirements, 1 inspection result is not eligible and 3 calculations are eligible with the following details:

a. Based on the calculation of the basic stress of the rail used at the concrete level crossing JPL 67 does not meet the requirements of 1141.896 kg/cm^2 because ≥ 1128 kg/cm^2.
b. The specifications of the fastening device used at the concrete level crossing JPL 67, the E-Clip fastening are in accordance with the technical requirements in the Minister of Transportation Regulation No. 60/2012.
c. Based on the results of the calculation of the lifespan of the concrete plate components at the concrete level crossing, it is found that the estimated service life is in accordance with the planned life of 10 years, but due to the calculation of

the plate thickness. If the concrete due to overloading is thicker than the design thickness of the concrete level crossing plate by 27%, then it is estimated that the service life of the concrete level crossing is less than 10 years.

d. Based on the results of the calculation of rotation and stability on the rubber rail used at the concrete level crossing, the rotation value in the long section is unqualified with a value of 5.701 MPa > 0.0154 MPa and the rotation value in the wide section is qualified with a value of 0.0083 MPa < 0.0154 MPa and for the stability value in the wide section does not meet the requirements with a value of 38.334 mm < 112 mm.
e. Based on the results of the tension calculation, sleepers used on the Temporary Track, at the initial prestressing stage, are eligible, but for the effective prestressing stage they are not eligible because they are greater than 200 kg/cm^2 due to the excessive load received due to the concrete level crossing component.

Based on the results of the calculation and evaluation of the railway components used in the concrete level crossing at JPL 67 Krian on the passing tonnage of the beating cycle with Multi Temper Tie (MTT) on the concrete level crossing JPL 67 is 1.17 times. times/year which means that the condition of the ballast at the concrete level crossing JPL 67 Krian requires a sacking cycle every 12 months so that the condition of the railroad is in good condition and does not interfere with the operation of passing railroad facilities.

Due to the inspection and maintenance at the crossing [10] cannot be done daily, the maintenance of railroad components is carried out simultaneously every 12 months during the process of ballasting using MTT, such as maintenance on concrete level crossing components in the form of epoxy concrete coating and inject grouting if there is structural damage to the concrete slab[11], replacement of inelastic rubber and maintenance on railroad components in the form of grinding and straightness maintenance on rail components, visual observation sleeper to replacement if severely damaged, tightening loose fasteners and replacing loose or missing fasteners.

4.2 Suggestion

a. It is necessary to carry out routine checks on concrete level crossing components that refer to the Minister of Transportation Regulation No. 31 of 2011.
b. It is necessary to conduct research on the use of R54 at level crossings in Indonesia.
c. There is a need to reassess the use of K-500 type concrete sleepers as railroad components in concrete level crossings.
d. It is necessary to conduct further studies on the use of rubber elastomeric bearings in concrete level crossings.

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