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Analysis of Railway Track Type Selection on the Lahat-Lubuklinggau Line

Windi Nopriyanto[1*], Septiana Widi Asuti[2], Puspita Dewi[3], Sapto Priyanto[4]
Politeknik Perkeretaapian Indonesia, Madiun, Indonesia
Email: windi@ppi.ac.id[1*], septiana@ppi.ac.id[2], puspita@ppi.ac.id[3], sapto@ppi.ac.id[4]
*Correspondence

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ABSTRACT

Currently, the railway line from Lahat to Lubuklinggau uses the R.42 rail type with a crossing power capacity of 2,106 > 5,106 tons/year. An increase in road class is needed to increase crossing capacity. This research aims to determine the feasibility and impact of upgrading the rail type from R.42 to R.54 to improve the operational efficiency and safety of the Lahat-Lubuklinggau railway line. In this study, the author uses the railway loading method using the beam on the elastic foundation (BoEF) concept to calculate rail permit voltage to ensure that the capacity of the railroad can accommodate the load of railway traffic. The study results in show that with the upgrade of the railroad class to class III with the R.54 rail type, this line can transport a load of 5,924,001.60 tons/year, an increase from 1,838,390.40 tons/year. In addition, the track with the R.54 rail type also meets the requirements for trains with the largest load, considering that the allowable voltage (1,097.18 kg/cm²) is smaller than the previous rail allowable voltage (1,738.14 kg/cm²). It is estimated that the R.54 rail type has a life resistance of 16-17 years against crossing power without the Babaranjang train and for 9-10 years against crossing power with the Babaranjang train for the coming year.

Introduction

To improve connectivity, South Sumatra Province is prioritizing the development of rail transportation modes (Ditjen Perkeretaapian, 2019). By utilizing funding sources from State Sharia Securities (SBSN) contained in the Budget Implementation List (DIPA) of the Palembang Class II Railway Engineering Center for the 2020-2021 fiscal year, the government has construed a railway line connecting Lubuk Linggau and Lahat with a total length of about 115 kilometers (Ditjen Perkeretaapian, 2019).

The Lahat-Lubuklinggau railway line needs improvements to improve operational performance and safety after 14 years since it was last updated in 2005. To achieve this goal, the Palembang Class II Railway Engineering Center has carried out the line improvement project. It is also planned to increase the frequency of train travel on the line to meet the need for cargo transportation capacity, especially coal. Demand for coal transportation services in the Sumatra region continues to trend upward (Sari et al., 2021). Based on Kusumo research (2021), a coal-only freight train known as Babaranjang uses a CC205 locomotive with a very strong attraction. This locomotive can pull up to 60 cars with a capacity of 50 tons per car, thanks to its axle load of 18 tons. In comparison, the CC202 locomotive is assigned to serve the Lahat-Lubuklinggau crossing for passenger and freight transportation, with a maximum axle load of 14 tons.

The Lahat-Lubuklinggau railway line still adopts R.42 type rail, which is classified as a class IV line with a limited carrying capacity of $2.10^6$2,106 > 5,106$5.10^6$ tons/year (Ditjen Perkeretaapian, 2020). With the increase in the capacity of the Babaranjang railway line, the potential for freight transportation can reach more than 5 million tons per year, considering that each car can load up to 50 tons of goods and a series of trains can consist of 60 cars. After the revitalization, the classification of railroads was upgraded to class III, which allowed the rail line to increase the carrying capacity of 5,106 > 10,106 tons per year by using R.54 type rails. The selection of rail type is based on calculating the rail structure by considering the rail foundation's centralized load and elastic properties. So, the amount of tension that occurs depends on the rail type (Mananoma et al., 2017; Yudistirani et al., 2021). Seeking to determine the condition of the rails and bearings on the Lahat-Lubuklinggau line, which are very old and do not meet safety and efficiency standards, revitalization is urgently needed by replacing larger and sturdier rails and bearings.

Rail transportation plays a crucial role in improving connectivity in South Sumatra Province, particularly in supporting efficient freight transport. This study examines the enhancement of rail type on the Lahat-Lubuklinggau railway line, which previously used R.42 type rail with a crossing capacity of 2,106 to 5,106 tons per year. The main goal of this research is to replace the rail with the R.54 type, which is expected to increase the load capacity to 5,924,001.60 tons per year, thereby improving operational efficiency and track safety.

The novelty of this research lies in its specific approach to increasing crossing capacity by addressing the unique challenges of railway infrastructure in Indonesia, particularly in South Sumatra, where infrastructure limitations and increasing demand for freight transport especially coal-pose significant challenges. Few studies have focused on upgrading rail types using the "beam on elastic foundation" (BoEF) approach in specific railway lines in Indonesia. In contrast, similar studies in other countries generally focus on main railway lines under different economic and geological conditions. This study provides specific context on how using the BoEF method can offer a solution to the unique challenges of the Lahat-Lubuklinggau line.

Furthermore, this study explicitly links the selection of track type with the improvement of operational safety and efficiency. Upgrading the rail type from R.42 to R.54 is expected not only to increase crossing capacity but also to contribute to enhanced operational safety. This is crucial given the high demand for coal transport in South Sumatra. By considering the comprehensive impact on operational efficiency and safety, this research aims to address the need for railway infrastructure revitalization to support local economic growth.

Methods

The research began with data collection to calculate the railroad's crossing capacity so that the load on the rail could be borne (Pyrgidis, 2022). It is necessary to know the types of passenger and freight trains that operate on the Lahat-Lubuklinggau route. With this data, finding the numbers of series on the train will also be possible. Some of it is also obtained from references to railway engineering and railroad books. The construction of railway lines depends heavily on how heavy the load will be, how fast the train will travel, and how often the train will pass. Then, an analysis of the loading of the railway was carried out. For the determination of the type of rail based on the calculation of rail dimensions, the assumption that the rail is a beam of infinite length is used (Utomo, 2009). Dengan pembebanan terpusat dan ditumpu oleh struktur yang mempunyai modulus elastisitas, yang dalam hal ini adalah modulus elastisitas. According to Rosyidi Rosyidi (2015), the loading of railways uses the concept *of Beam on Elastic Foundation* (BoEF) to calculate the stress of railway loading components. Calculating the change in the load of a moving wheel to a stationary load using the Talbot formula (Munawwarah & Herijanto, 2020). Here is how to find out the voltage on the rails:

1. Dumping factor

$$\lambda =$$

2. Dynamic load calculation using the TALBOT equation

   Pd = Ps (1+ 0,01($\frac{Vr}{1.609}$ – 5))

3. Calculation of moments due to locomotive load

   Ma = 0,85 x $\frac{Pd\,Pd}{4\,\lambda 4\,\lambda}$

4. Overview of the basic stress on the rails

   $S_{base} = \frac{Ma}{Wb}$

5. Check the base voltage

$$S_{base} < Rail\ base\ voltage\ (kg/cm^2)$$

6. Plan tension on rails; and

$$\sigma = \frac{Ma.Yb}{lx}$$

7. Check the voltage σ < Rail clearance voltage (kg/cm²)

$$\sigma < Rail\ clearance\ voltage\ (kg/cm^2)$$

In the analysis of rail loading, the tension on the rails in the field will be possible to determine using the rail tension allowed in PM No.60 of 2012 (Menteri Perhubungan, 2012). Thus, the feasibility of using this type of rail on the Lahat-Lubuklinggau railway line will be known.

Data Collection Methods

This study adopts a secondary data approach, as Sugiyono (2018) explained, namely data obtained from other research sources. Secondary data was obtained from various agencies, including the Palembang Class II Railway Engineering Center, responsible for the budget and the implementation of related activities. In addition, the data also comes from PT. Kereta Api Indonesia is an operator and DED (*Detail Engineering Design*) construction consultancy services that plan the track layout design on the Lahat-Lubuklinggau crossing in 2020. Some other data was obtained from PT. Indonesian Railways and reference books related to railroad construction. According to Heryana et al. (2019), secondary data is ready to use because it has been collected and processed by others. In other words, the researcher only obtains the data indirectly.

Data Analysis Methods

Based on data obtained from construction consulting agencies and services related to the implementation of road class improvement activities for the Lahat-Lubuklinggau railway line, as follows:

1. Railway Cross-Force Analysis

Railway crossing power determines the value of the tension on the rails. The goal is to determine whether the rail components meet the requirements so that it is known if they need to be replaced (Jaya & Miswanto, 2019). This data was obtained from PT. Indonesian Railways, this is needed to determine the types of passenger and freight trains operating on the Lahat-Lubuklinggau crossing. With this data, finding the number of series on the train will also be possible. Some of it is also obtained from the reference of railway engineering and railway road books.

2. Railway Load Analysis

The construction of railway lines is highly dependent on the load carried, the maximum speed of the train, the axle load, and the pattern of railway operation (Adityadharma et al., 2004; Trimayanita, 2021). The analysis of rail loading is based on the Regulation of the Minister of Transportation Number PM.60 of 2012 concerning Technical Requirements for Railway Lines as a reference according to the requirements in the analysis of the structure of the railway, especially the upper structure, namely the Rail.

Results and Discussion

Result

Railway Network Load Analysis,

On the Lahat-Lubuklinggalu station crossing, the CC202 type locomotive, which drives passenger and freight trains, is often passed. In the ongoing revitalization activities, a plan is to strengthen this line by bringing in new trains specifically for transporting coal. The locomotive to be used is the CC205 type, which has a bogie with 3 axles. The following explains the calculation of axle load and wheel load on locomotives of type CC202 and CC205 and their train series.

Table 1. Train Load Calculation (Ton)

Train Type	Train Weight	Gaya Bogie (Pb) Wlok / 2	Gaya Gandar (Pg) Pb / 2	Gaya Roda (Pr) Pg / 2
Lokomotiv CC202	84	42	14	7

Locomotive CC205	108	54	18	9
Passenger train	40	20	10	5
Dining Train	41	20,5	10,25	5,125
Freight Train	35	17,5	8,75	4,325
Train Generator	42	21	10,5	5,25

From the explanation above, it can be determined that the CC205 type locomotive with 3 axles has the largest load, which is 108 tons. The bogie load is 54 tons, the load per axle is 18 tons, and the load on the wheels is 9 tons.

Railway Cross-Force Analysis

1. **Calculation of Railway Cross Power Load**

Table 2. Calculation of Cross-Power Load

Trip KAl	Daily Cross Power Load (Tonnage)						Description
	Locomotive	Passenger Carriage	Gb. Makan	Gb. Pembangkit	Gb. Katel	Gb. Bongkar	
KAl Executive Business Passenger	164	560	82	84	-	-	2 x perkal
KAl Economy Passenger	164	480	82	84	-	-	2 x perkal
KAl Fuel	84	-	-	-	700		1 x perkal
KAl Babaranjang	108	-	-	-	-	3.000	1 x perkal
Total	520	1.040	164	168	700	3.000	
Grand Totals	5,592 tons/day						

From the results of the calculation of the Cross Power Load on the train on the Lahat-Lubuklinggau Route, then:

a. Cross-Transport Capacity next year (without long-range coal trains): Passenger Train + Freight Train is 2,484 tons/day.
b. Cross-transport capacity in the coming year (with long-range coal trains): Passenger Train + Freight Train + Long-Range Coal Train reaches 5,592 tons/day.

2. **Analisa Daya Lintas Berdasarkan Tonase Lintas**

Cross Carrying Capacity is the number of transportations that passes through a crossing in one year, with the following calculation formula:

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

T = 360 x S x TE

a. If the Cross-Transport Capacity in the coming year (without Long Series Coal trains)

TE = 1372+ (1,3 x 2072) + (1,4 x 412)
at = 4.642,40 to/green
So, for the annual Daya Lintas is calculated as follows:
T = 360 x S x TE
T = 360 x 1,1 x 4.642,40
T = 1,838,390.40 tons/year

b. Prediction of Cross Transport Capacity (with Babaranjang Train)
TE = 1372 + (1,3 x 3892) + (1,4 x 520)
TE = 14,959.60 tons/day

So, the annual cross-annual capacity is calculated as follows:
T = 360 x S x TE
T = 360 x 1,1 x 14959,60
T = 5.924.001,60 from/bottom

The calculations' results show that the normal cross-transport capacity (without the Babaranjang train) is 1,838,390.40 tons/year, while the cross-transport capacity with the Babaranjang train reaches 5,924,001.60 tons/year. Thus, it is included in the category of railroad class III with a maximum speed of 100 km/h (Table 2 Rail Road Class) and a cross-transport capacity of 5.10^6 - 10.10^6 million tons/year.

Life Resistance Analysis

Table 3. Calculation of Rail Life Durability R. 42 and R. 54

Account	Formula	Results at R 42	Results at R 54
Dumping Factor	$\lambda = \left(\frac{K}{4\,EI}\right)^{\frac{1}{4}}\left(\frac{K}{4\,EI}\right)^{\frac{1}{4}}$	0,011185295	0,0097771571
Dynamis Load	$Pd = Pr\ (1+\ 0{,}01(\frac{Vr}{1{,}609}\frac{Vr}{1{,}609} - 5))$	15.541,92 kg	15.541,92 kg
Moment Due to Locomotive Load	$Mal = 0{,}85\ \frac{Pd\,Pd}{4\,\lambda 4\,\lambda}$	347.373,94 kg/cm²	337.793,28 kg/cm²
Base Voltage on Rails	$S_{base}S_{base} = \frac{Ma}{Wb}\frac{Ma}{Wb}$	1.725,20 kg/cm²	1094,31 kg/cm²
Check Base Voltage	$S_{base}S_{base} < S_dS_d$	1.725,20 kg/cm² > 1.410 kg/cm² (tidak ok)	1094,31 kg/cm² < 1097 kg/cm² (ok)
Tension on Rails	$\sigma x = \frac{Ma.yb}{I}$ $\sigma x = \frac{Ma.yb}{I}$	1.738,14 kg/cm²	1.097,18 kg/cm²
Check Allowable Voltage	$\sigma x \sigma x < \sigma\sigma$	1.738,14 kg/cm² > 1.663 kg/cm² (tidak ok)	1.097,18 kg/cm² < 1.663 kg/cm² (ok)

Based on the calculation results, the planned basic voltage on the R.42 rail is 1,725.20 kg/cm², greater than the permitted voltage of 1,410 kg/cm², so it is not eligible for use. The voltage that occurred was also greater than the permitted voltage, which was 1,738.14 kg/cm² > 1,663 kg/cm². Therefore, the old rail of type R.42 is not feasible and needs to be replaced with a stronger rail.

On the contrary, the calculation results on the R.54 rail show that the planned basic voltage of 1094.31 kg/cm² is less than the permitted voltage of 1097 kg/cm², meeting the set conditions. The voltage that occurs is also smaller than the allowable voltage for the R.54 type rail road class, which is 1,097.18 kg/cm² < 1,663 kg/cm². Therefore, R. 54-type rails are feasible to use.

Conclusion

Based on the results of the research on the revitalization of the Lahat-Lubuklinggau railway line, the current cross-transport capacity is only around 1,838,390.40 tons per year is expected to increase significantly to 5,924,001.60 tons per year with the operation of the Babaranjang coal train: The construction conditions on the railroad show that the R.42 rail is not suitable for use because the voltage that occurs (1,738.14 kg/cm²) exceeds the allowable voltage (1,663 kg/cm²), while the R.54 rail is qualified because the voltage that occurs (1,097.18 kg/cm²) is less than the allowable voltage, with the durability of the R.54 rail estimated at 16-17 years without the Babaranjang train and 9-10 years with the Babaranjang train; It is recommended that further research include a study of the construction of the lower part of the railroad such as soil carrying capacity, subgrades, ballasts, and supporting accessories so that the planning results are more accurate.

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