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# Performance Evaluation of Freight Train Wooden Sleepers on the BH 77 Tegineneng Bridge

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***ABSTRACT***

*Rail transport is very important in supporting human mobility and distribution of goods for heavy loads such as coal. The BH 77 Tegineneng Bridge in Sumatra is a critical infrastructure that supports coal transportation. In its structural components, wooden sleepers are used on this bridge. The wooden sleepers used must withstand dynamic, shock, lateral, and longitudinal loads. This is to ensure the stability and operational safety of the bridge. This study aims to evaluate the performance of wooden sleepers on the BH 77 Tegineneng Bridge. A case study approach was used with field data on axle loads, including static and dynamic loads, collected and analyzed to determine the load distribution and structural response. The results show that the dynamic load with a Dynamic Amplification Factor of 1.86, coupled with a shock load reaching 56,784 kN, exerts significant stress on the sleepers. The wooden sleepers effectively absorb dynamic forces, distribute the load evenly, and demonstrate resilience under repeated loading cycles, with a maximum bearing load of 189.28 kN. These findings emphasize the suitability of wood as a sleeper material due to its elasticity and damping properties, which offers a durable and efficient railway infrastructure. This study contributes to demonstrating the characteristics of wooden sleepers as a basis for material selection in freight railway systems.*

## 1. Introduction

Rail transportation is one of the land transportation modes that plays a strategic role in supporting human mobility and good distribution. In addition to being favored by the public as an intercity mode of transportation, railways are also the primary choice for transporting heavy loads such as mining materials, industrial products, and other commodities, thanks to their large transport capacity [1]–[4]. With better energy efficiency compared to other transportation modes, railways provide an economical and environmentally friendly solution. This is particularly relevant on a large scale, where cost efficiency and low environmental impact are critical factors in supporting national and global logistics systems.

As part of the rail transportation system, bridges play a very important role, especially on routes that traverse challenging terrains such as rivers, valleys, or hilly areas [5]–[10]. Railway bridges are designed to withstand heavy loads from freight trains, both static and dynamic loads [11]. Dynamic loads generated by train movements, such as sudden braking, acceleration, or changes in direction, impose additional stress on the bridge structure [12]–[15]. This makes the design and selection of bridge materials a crucial factor in ensuring the smooth operation of railway services and maintaining infrastructure safety.

One of the railway bridges with a strategic role is the BH 77 Tegineneng Bridge in Sumatra. This bridge serves as a main route for transporting coal, one of the key commodities supporting the regional economy. Due to its vital function, the performance of the bridge structure, including the wooden sleepers used, needs to be comprehensively evaluated. This bridge uses wood as the material for its rail sleepers. Dynamic loads generated by freight trains such as coal trains often exceed static loads, exerting significant pressure on the sleepers [16]. Additionally, lateral and longitudinal forces caused by braking, acceleration, or bending further challenge the sleeper material to maintain structural stability over the long term.

In addition to the main structure of the bridge, supporting elements such as rail sleepers also play an important role in maintaining stability and load distribution. These sleepers not only support the rails on the bridge but also help to absorb the energy from the dynamic loads applied [17]. In this context, the selection of sleeper materials such as wood, concrete, or steel becomes a crucial topic to ensure durability and operational efficiency. In various locations, wood is still the main choice as a rail sleepers material because it has good elasticity and insulating properties, making it suitable for carrying live loads on steel railway bridges [18]. Wooden sleepers are less sensitive to temperature changes than other materials, which can be beneficial in extreme climates [19]. Apart from that, wood is quite easy to handle and install because it is lighter in weight than concrete or steel sleepers [20].

Previous research has provided various insights into the performance of sleeper materials in railway infrastructure [21], [22]. Studies have shown that materials such as concrete have high strength but are less able to dampen dynamic loads effectively [23]. Other research identified that steel materials in sleepers offer good resistance to cyclic loads, but can experience material fatigue more quickly under conditions of extreme repetitive loads [24]. As an alternative, wood material has natural damping properties which help reduce stress concentrations due to dynamic loads [20]. However, wood also has weaknesses such as a short

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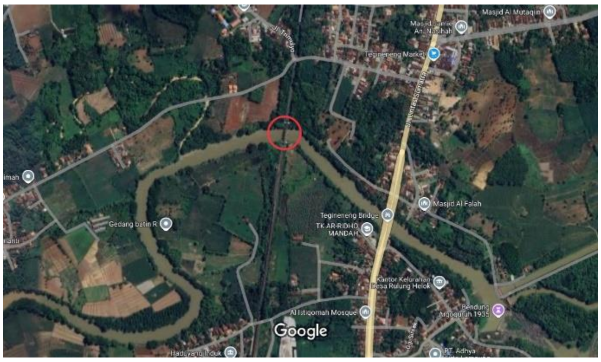
lifespan, susceptibility to termite damage, split ends, and rot due to fungus [25]. A study of various materials shows that each type of material has its own advantages and limitations depending on the load conditions and operational environment [26].

Although previous research has reviewed the advantages and disadvantages as well as the performance of wooden materials as rail sleepers. However, research related to evaluating the performance of wood materials as railway track pillows specifically for bridges that transport heavy goods such as coal has not been widely explored. Evaluation is important because the performance of wooden sleepers in facing pressure due to repeated dynamic, shock, lateral and longitudinal loads needs to be evaluated.

This research aims to evaluate the performance of wooden sleepers on the BH 77 Tegineneng Bridge. The load distribution and performance of wooden materials as railway sleepers will be investigated. Expected outcomes include a deeper understanding of how wood materials behave under dynamic loads. So that it can provide better guidance in the selection of sleeper materials for railway bridge applications that serve the transportation of heavy goods.

## 2. Research Method

This research uses a case study approach to analyze the performance of wooden sleepers on the BH 77 Tegineneng railway bridge (**Figure 1**) in facing dynamic, shock, lateral, longitudinal loads, as well as the distribution of loads received. The research began with collecting axial load data from passenger and freight train wheels through direct measurements in the field, which was then processed into dynamic load data using the Dynamic Amplification Factor calculation method. The data obtained were used to evaluate the load distribution, stresses and structural response of the wooden sleepers under various load conditions. This analysis was carried out by comparing the results of field observations with the applicable material standards according to PM No. 60 of 2012 to ensure the suitability of the materials and designs used for the operational conditions of railway tracks in Indonesia.




*Source : Google Maps (2024).*

**Figure 1.** BH 77 Tegineneng Bridge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150 - 160
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## 2.1 Data

The main data used in this research includes axial load data from train wheels, which were collected through direct measurements using a load measuring device at the BH 77 Tegineneng bridge location. Measurements were carried out during the train's normal operational period to obtain representative data. This data includes

a) Static and dynamic loads

The dynamic load value of 33.43 tons per axle. For passenger and freight trains with a maximum load capacity of 18 tons per axle.

b) Lateral and Longitudinal Load

The lateral load is calculated at 15% of the axle load, namely 2.7 tonnes per axle for a maximum load of 18 tonnes. These loads are significant on curves or snake motion tracks, which increase the lateral pressure on the rail. Longitudinal loads due to braking and acceleration produce a force of 47.32 kN, providing additional stress that affects the stability of the rail and joints.In addition, significant longitudinal forces due to braking can trigger structural failure in the rail if there are no suitable flexible dampers [27]–[29]. Therefore, the combination of lateral and longitudinal stability is key in increasing the durability of train tracks, especially on tracks with high traffic.

c) Shock load

The shock load resulting from braking and acceleration produces an additional force of 56,784 kN. This data is used to evaluate the structural response of wooden sleepers and ensure even load distribution across the entire sleeper, thereby supporting analysis of service life and maintenance requirements.

## 2.2 Data Analysis

a) Dynamic Amplification Factor

DAF is a dimensionless number which is the result of comparing the changes that occur due to the dynamic load applied to the bridge with the changes that occur to the bridge due to the bridge's static load.

$$DAF = \frac{Ddyn}{Dstat} \tag{1}$$

b) Load Distribution

Load distribution analysis was carried out by measuring the axial load from the train wheels on the bearings using a direct load measuring device at the BH 77 Tegineneng Bridge location. Static and dynamic load data is then processed to determine the load distribution pattern on each rail bearing. The analysis is carried out by dividing the total train load into the


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bearings based on their relative position to the wheels, where the bearings directly under the wheels receive 40% of the load, and the remaining load is distributed proportionally to the surrounding bearings, amounting to 23% and 7% respectively. These results are used to evaluate the bearing's effectiveness in distributing loads evenly and reducing stress concentrations, thereby supporting long-term structural stability.

c) Slepeers Performance

The performance of the wooden bearings on the BH 77 Tegineneng Bridge was analyzed based on their ability to absorb dynamic loads, distribute loads evenly, and deal with horizontal and longitudinal forces that influence structural stability. The analysis also includes resistance to repeated load cycles and the material's ability to absorb dynamic energy to support long-term stability. This approach provides a basis for assessing the suitability of wood as a rail sleeper material for railway infrastructure.

## 3. Results and Discussions

### 3.1 Dynamic Amplification Factor

The dynamic amplification factor (DAF) of 1.86, with a maximum dynamic load reaching 33.43 tonnes per axle for a maximum load of 18 tonnes, shows that the dynamic load experienced is much greater than the static load. A high DAF value indicates that the rail sleeper must be able to withstand significant cyclic and dynamic loads without showing signs of premature failure. With high dynamic loads, selecting the right sleeper material becomes very important. Sleeper materials must have a high damping capacity to absorb dynamic energy while being able to maintain its structural integrity without failure [22], [30]–[34].

### 3.2 Sleepers Distance

The optimal distance between sleepers is 0.6 meters, according to PM standard No.60/2012. The choice of this distance is based on load distribution studies which show that sleeper distances that are smaller than standard tend to increase stress concentrations at certain points, while distances that are too large risk causing excessive stress. Previous research shows that a distance between sleepers of 0.8 meters provides optimal load distribution for freight trains with a load of 22 tons [35]. With optimal clearance design, excess stress on the sleeper can be minimized, thereby extending service life and reducing maintenance costs.

### 3.3 Loads Distribution

The load received by the sleepers depends on the force distribution of the train wheels. The load distribution is shown in **Table 1**.


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150 - 160
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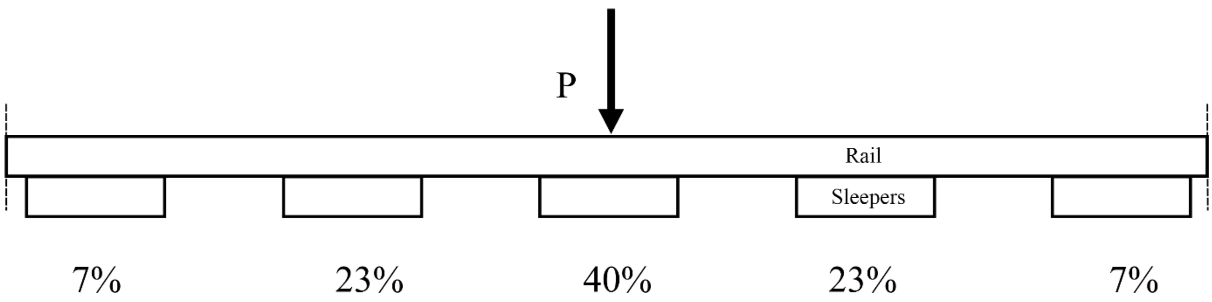
ISSN (*Print*) 2502-9304

**Table 1**. Load Distribution on Sleepers

| | **B1** | **B2** | **B3** | **B4** | **B5** | **B6** |
|---|---|---|---|---|---|---|
| Due to P1 | 23% | 40% | 23% | 7% | 0% | 0% |
| Due to P2 | 0% | 7% | 23% | 40% | 23% | 7% |
| Due to P3 | 0% | 0% | 0% | 7% | 23% | 40% |
| Total (%) | 23% | 47% | 46% | 54% | 46% | 47% |
| Total (kN) | 76.4 | 156.16 | 152.84 | 189.28 | 152.84 | 156.16 |

*Source: Author's Analysis Results (2024).*

The load distribution on the sleepers shows a specific pattern according to the table. Sleepers (B) receive loads distributed from the train wheels (P), with different load distributions at each sleepers position. The load distribution pattern depicted is that the sleepers directly under the wheel will receive a load distribution of 40% of the total load, as shown at point P1 on sleepers B1, point P2 on sleepers B4, and point P3 on sleepers B6. Furthermore, the sleepers located around the wheel point will receive a load distribution of 23%, and further away the sleepers will receive 7%, as illustrated in **Figure 2**. This shows that the sleepers that are closer to the train wheel point receive a greater load than the sleepers that are further away. In load distribution, the main load will be distributed by the sleeper closest to the point of force, while the surrounding sleepers play a role in distributing the remaining load evenly [36].




*Source: Author's Analysis Results (2024).*

**Figure 2.** Load Distribution on Sleepers

The total load received by each sleeper ranges from 23% to 54% or 76.4 kN to 189.28 kN. Wood material is used in the sleepers to handle this total load efficiently. With its natural elastic properties, wood is able to absorb the dynamic energy generated by a load of 189.28 kN, reducing the risk of permanent deformation. In addition, the even distribution of the load on the wood material ensures that the force is not concentrated in one point, which can cause material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fatigue more quickly. Previous research showed a similar thing, where wood material was able to accept loads of up to 200 kN [37]. This confirms that the use of wood as a sleeper material can supports even load distribution, but also ensures long-term structural stability. Wood, which has high elasticity and damping properties, is able to increase the operational efficiency of train tracks on lines that have high dynamic loads

### 3.4 Wood Sleepers Performance

The wooden sleepers are capable of absorbing dynamic loads of up to 33.43 tons per axle without showing signs of premature fatigue. Wooden sleepers effectively distribute the load evenly along the structure, reducing stress concentrations at certain points. This can be seen from the load distribution pattern analyzed in the research, where the heaviest load is absorbed by the bearing directly under the wheel, while the remaining load is distributed to the surrounding bearings. The analysis also shows that the natural flexibility of wood allows for even distribution of dynamic loads, which is essential to avoid stress concentrations at specific points

The analysis of horizontal forces acting on the BH 77 Tegineneng Bridge reveals two primary directions of load: perpendicular and longitudinal to the railway axis. Perpendicular forces arise from the lateral motion of trains, commonly referred to as "snake motion," as well as wind forces and centrifugal forces encountered when the train negotiates curves. These forces significantly impact the track infrastructure, especially on bridges and curves, where maintaining stability is critical. Longitudinal forces, on the other hand, result from braking forces, friction between the train wheels and rails, and gravitational forces on inclines or declines. The braking force generates additional horizontal loads that must be counterbalanced to prevent excessive stress on the track structure. Thermal expansion and contraction of the rails further contribute to longitudinal stress, requiring the incorporation of expansion joints and flexible sleepers to mitigate these variations. Meanwhile, wooden sleepers show better performance with the ability to absorb dynamic energy without premature damage, supporting long-term stability. Previous research revealed that materials with high damping properties such as wood can extend the service life of structures and reduce maintenance requirements. Therefore, wood is a very appropriate choice for rail sleepers with high dynamic loads.

## 4. Conclusion

This research shows that wooden sleepers have advantages in absorbing dynamic loads, distributing forces evenly, and maintaining the stability of the rail structure. With the


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N. Pamursari/ U Karst Vol 08 No.02 Year 2024 ISSN (*Print*) 2502-9304
ability to withstand a maximum load of up to 189.28 kN without premature damage, wood has proven to be a reliable material for use on rail lines with high dynamic loads. The load distribution pattern shows that the load is distributed with a maximum value of 40% of the total load on the sleepers under the wheels, while the surrounding sleepers play a role in distributing the remaining load gradually until they reach a minimum point of 7%. This shows that wood is able to reduce dynamic energy effectively and stress concentrations that can cause permanent deformation in the ballast. These findings provide design guidance for selecting sleepers materials that can increase load transfer efficiency in railway rail systems. The advantages of wood in reducing dynamic energy and distributing loads evenly offers a material solution that can extend the life of infrastructure, reduce maintenance needs, and be able to distribute the load to the ballast well.

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