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Geometric Evaluation of Transport Road from P6000BK14 to Disposal at PT. Sinar Nirwana Sari West Kutai East Kalimantan

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Abstract

PT. Sinar Nirwana Sari is a company operating in the coal mining sector with the main activity of transporting materials from the mining front to the disposal area. The condition of the haul road at the research location still shows several discrepancies with road geometry standards, which have the potential to affect the level of productivity and operational safety of hauling equipment. Therefore, this study was conducted with the aim of evaluating the geometry of the haul road based on applicable technical parameters. The method used was the direct measurement method in the field. Data collected were road width, road width on bends, height difference, and bend radius. Furthermore, the data was analyzed with reference to the AASHTO standard. The analysis results showed that the road width on the straight segment had an average value of 16.4 meters, which has met the minimum standard of 15 meters. Meanwhile, the road width on bends had an average value of 20.7 meters, thus meeting the minimum standard of 18.45 meters. The road slope value (grade) was below the maximum limit of 8%, so it was still considered safe. However, the superelevation values, which ranged from 0.8% to 9.2%, indicate that some curves do not meet the recommended 4%. Based on the evaluation results, the average curve width of 20.7 m has met the minimum AASHTO standard of 18.45 m. However, widening is still required on several curve segments that do not meet the minimum standard, while improvements in superelevation are needed on several curves to improve safety and operational efficiency of transportation vehicles.

Keywords: AASHTO; cross slope; haul road; superelevation; road geometry

1. Introduction

Transportation is a crucial aspect of mining operations, particularly in the process of moving material from the mining front (pit) to the disposal or stockpiling area. This activity is not only related to the distribution of mining products, but also plays a role in supporting the movement of equipment and labor within the mining area. Therefore, the existence of haul roads that meet technical standards is crucial to ensure smooth operations, work safety, and efficient mining production [1]–[3].

Haul roads in mining activities need to be designed and maintained in accordance with applicable geometric standards to optimally support the movement of haulage equipment. Road geometric parameters include road width, slope (grade), and curve design, which must be adapted to the characteristics and dimensions of the haulage equipment used [4]–[6].

The width of the haul road is determined by the number of traffic lanes and the size of the haul vehicle, while the curve design is related to the vehicle's maneuverability. In addition, the road gradient has a significant influence on the performance of the haul vehicle, especially in terms of climbing ability and fuel consumption [7]–[9].

The difference between planning conditions and actual conditions in the field is generally influenced by operational factors, topographic conditions, and limitations in the implementation of mining road construction. Therefore, a technical evaluation of the haul road geometry is required to determine its level of compliance with the standards used [10], [11].

Based on field observations, several narrow road sections, sharp bends, and inadequate superelevation were still found, so an actual geometric evaluation is needed. Through the geometric evaluation of the haul road, it is hoped that the function of the road as the main means of transportation in mining activities can run optimally and improve work safety and operational efficiency [12]–[14].

2. Research Methodology

When planning mining roads, both for access to mining areas and for stockpiling operations, various geometric aspects are required. These considerations will influence

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the overall shape of the mining area. Road geometry includes road width and slope, which are significantly affected by hauling equipment used in mining activities. Haul roads are vital for supporting the smooth operation of the production process. Therefore, road conditions must be able to support the weight of the vehicles and the materials being transported.

In general, mining roads can be divided into several types, including mine roads, main roads, stripping roads, and disposal roads. Essentially, the requirements for mining haul roads are similar to those for general roads, both in urban and rural areas. However, the main difference lies in the road surface. Mining haul roads are generally not paved because they are not permanent and frequently used by heavy equipment, thus placing greater emphasis on strength and ease of maintenance than on permanent pavement.

2.1. Method

This research was conducted through direct field measurements using a Topcon ES-105 Total Station to obtain *X*, *Y*, and *Z* coordinate data on the haul route from P6000BK14 to the disposal site at PT Sinar Nirwana Sari. Observations were conducted on 14 straight road segments and 6 curves representing the entire research route. Measurements were carried out on dry road surfaces to ensure that the observation results were not affected by puddles or muddy road conditions. Road width was measured on each straight and curve segment, from the left edge to the right edge of the road body. Elevation data was taken at the start and end points of each road segment to determine the height difference between observation points. The grade value was calculated based on the difference in elevation of two points divided by the horizontal distance between the points, then multiplied by 100 percent. Furthermore, the measurement data was processed using 3DMine software to obtain the road profile, longitudinal slope, and other geometric parameters. Analysis was carried out on road width, curve width, grade, and superelevation with reference to the AASHTO (2011) standard. The AASHTO standard was chosen in this study because it has complete road geometry parameters and is commonly used as a reference in evaluating mining haul roads, especially for the analysis of road width, curves, grades, and superelevation. In addition, this standard has been widely used in similar studies, making it easier to compare research results. Other standards such as the ESDM Ministerial Decree are used as general safety guidelines, but do not provide geometric parameters as comprehensive as AASHTO. to determine the level of suitability of road conditions in the field at PT. Sinar Nirwana Sari. The next stage is the process of processing data that has been obtained from field measurement activities. At this stage, an analysis of the geometric parameters of the haul road is carried out.

The analysis includes determining the road alignment, which includes calculating the road width when straight and the road width when curved. To determine the haul road width when straight, the following equation is used:

$$L = n\,Wt + (n+1)(X) \quad (1)$$

$$X = 1/2\,Wt \quad (2)$$

where,
L : Width of haul road (m)
n : Number of lines
Wt : Width of the vehicle (m)

To calculate the width of the road on a bend. The formula used is:

$$Wmin = n(u + Fa + Fb + Z) + C \quad (3)$$

$$Z = (u + Fa + Fb)/2 \quad (4)$$

where,
W : Width of the haul road at the bend (m)
n : Number of lines
u : Width of wheel track (m)
Fa : Front hanging width (m)
Fb : Rear overhang width (m)
Z : Width of the roadside (m)
C : Safe distance between vehicles (m)

Calculation of bend radius, superelevation and longitudinal slope of the road.

To calculate the bend radius, the formula used is:

$$R = \frac{w}{\sin\beta} \quad (5)$$

where,
R : Radius of curve of haul road (m)
w : distance between front and rear axles (m)
$\sin\beta$: front wheel deflection angle (°)

To calculate superelevation, the formula used is:

$$e = -\mathrm{f}\frac{Vr^2}{127R} \quad (6)$$

where,
e : Superelevation
Vr : Plan speed
R : Curve radius
f : Lateral friction coefficient
127 : Constant

To calculate the longitudinal slope of a road, the formula used is:

$$Grade(\%) = \frac{\Delta h}{L}\ 100 \quad (7)$$

where,
Δh : Difference in Elevation (m)
L : Horizontal length of road (m)

3. Results and Discussion

The research location is in the Benangin area of West Kutai, East Kalimantan, specifically within the concession area of PT. Sinar Nirwana Sari (SNS). The research location and haul road route from P6000BK14 to the disposal area are presented in Fig. 1.

The haul road at PT Sinar Nirwana Sari is a two-lane road connecting the P6000BK14 area with the disposal area. Field measurements show the haul road's width varies between 13.2 and 19.5 meters.

The road width requirement was calculated based on the specifications of the transport equipment used, namely the CMT-106 dump truck, with an overall vehicle width of 4.1 m. The analysis was carried out for straight and curved road conditions on two lanes. From the results of calculations using the AASHTO method, it was obtained that the minimum width of a straight road for two lanes is 14.35 meters. The comparison between the measured road width in the field and the AASHTO standard is presented in Table 1 [1], [3].

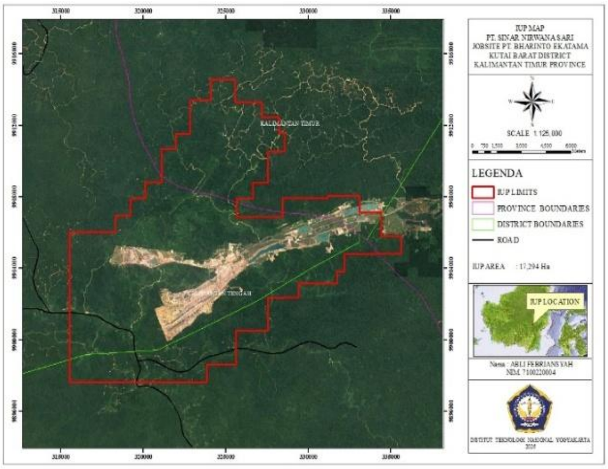

Figure 1. Research Location

Table 1. Straight road width

Road Segment	Road Width (m)	AASHTO Standard Width (m)	Information	Repair (m)
AB	17.5	15	Straight 2 Lanes	0
BC	16.7	15	Straight 2 Lanes	0
CD	18	15	Straight 2 Lanes	0
DE	16.2	15	Straight 2 Lanes	0
EF	14.7	15	Straight 2 Lanes	+0.3
FG	14	15	Straight 2 Lanes	+1
GH	17.3	15	Straight 2 Lanes	0
HI	19	15	Straight 2 Lanes	0
IJ	18.9	15	Straight 2 Lanes	0
JX	13.7	15	Straight 2 Lanes	+1.3
FK	19.5	15	Straight 2 Lanes	0
KL	18.8	15	Straight 2 Lanes	0
LM	16.9	15	Straight 2 Lanes	0
MW	13.2	15	Straight 2 Lanes	+1.8

The data in Table 1 shows that the average width of a straight two-lane road is 16.4 meters. The variation of road width between segments is illustrated in Fig. 2. Overall, this meets standards, but some sections still require adjustments in the form of wider road widths.

Based on the minimum width requirement of 18.45 meters for two-lane haul roads on bends, the results show that the average curve width has met the required standard. The detailed evaluation results of the curve width for each segment are presented in Table 2. However, several curve segments still have widths below the minimum requirement and therefore require widening [7], [8].

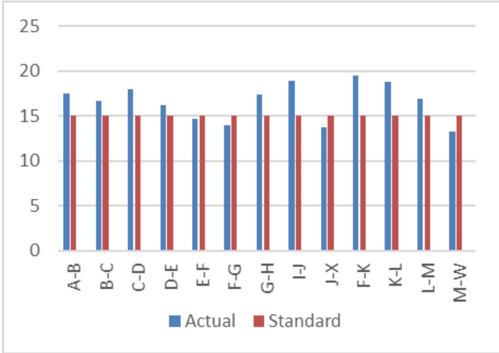

Figure 2. Road width graph

Table 2. Width of bending roads

Bend	Segment Point	Number of Lines	Width (m)	Repair (m)
I	A	2-lane turn	17.5	+0.9
II	B	2-lane turn	23.5	0
III	C	2-lane turn	26.7	0
IV	D	2-lane turn	21.4	0
V	E	2-lane turn	18.5	0
IV	F	2-lane turn	16.6	+1.85

The average width of the road at the bend is 20.7 meters, exceeding the minimum standard of 18.45 meters. Nevertheless, curve segments A and F have widths of 17.5 m and 16.6 m respectively, which are below the standard and therefore require widening.

Referring to the AASHTO standard (2011), the recommended grade value for transport equipment is around 8%. The calculated longitudinal slope (grade) values for each road segment are presented in Table 3 [1], [2], [15].

Table 3. Straight road width

Segment	Initial Elevation	Final Elevation	Δh (m)	Distance (m)	Grade (%)	Required Improvement
AB	59	59	0	100	0	0
BC	59	59.6	0.6	100	0.6	0
CD	59.6	62	2.4	50	4.8	0
DE	62	66	4	100	4	0
EF	66.9	72.9	6	100	6	0
FG	72.9	77	4.1	100	4.1	0
GH	77	77.8	0.8	100	0.8	0
HI	77.8	84.1	6.3	100	6.3	0
IJ	84.1	88	3.9	100	3.9	0
JX	88	86.3	-1.7	100	-1.7	0
FK	86.3	87	0.7	100	0.7	0
KL	87	87.9	0.9	100	0.9	0
LM	87.9	90	2.1	100	2.1	0
MW	90	91.6	1.6	125	1.28	0

Adjusting the grade to meet standards can be done by adjusting the road elevation difference. This can be achieved through cut and fill work, either by reducing or adding material to specific areas.

Based on the AASHTO reference, the recommended superelevation is 4%. From the analysis results, it was found that the planned bend width is 20.7 meters with a standard bend radius of 14.31 meters. The calculated superelevation values for each curve segment are presented in Table 4 at a speed of 20 km/h [1], [8], [9].

Table 4. Superelevation

No	Bend Width (m)	Radius (R) (m)	Superelevation (%)	Repair
A	17.5	13	6.2	0
B	23.5	15.41	2.4	+1.6%
C	26.7	16.05	1.9	+2.1%
D	21.4	15	2.9	+1.1%
E	18.5	14	4.4	0
F	16.6	13	6.2	0

The evaluation results indicate that elevation adjustments are required on several road segments. Mismatched haul road geometry can directly impact dump truck performance. Roads that are too narrow can potentially slow down vehicles when passing each other, while sharp bends and low superelevations can reduce safe cornering speeds. Excessively high grades increase engine workload, increase fuel consumption, and extend transport cycle times. Furthermore, poor geometric conditions also increase the risk of slips, rollovers, and mining traffic accidents.

In general, a good transverse slope of a mining road is 40 mm/m, which means that every 1 meter of horizontal distance has a height difference of 4 cm [11], [12].

Based on the data and theoretical references used, the calculation of the transverse slope is obtained as follows:

$$a = 1/2 \times 15\text{m} = 7.5\text{m}$$

$$b = 7.5m \times 40\text{mm/m}$$

Fig. 3 shows the cross-section of a straight haul road illustrating the cross slope used to facilitate surface drainage and maintain road surface stability.

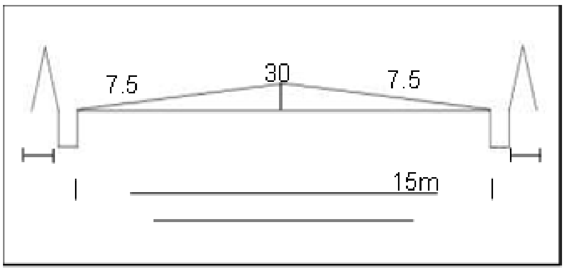

Figure 3. Cross-section of a straight road

So to overcome the drainage problem so that the road surface is not flooded by water and the road surface is not easily damaged, the haul road at PT Sinar Nirwana Sari, especially the haul road on a straight road with a minimum width of 15 meters, the good transverse slope is 30 cm.

4. Conclusion and Suggestions

The geometry of the haul road that meets safety aspects on straight and curved routes for the CMT 106 dump truck at PT Sinar Nirwana Sari can be explained as follows: The haul road width on the straight segment was planned at 15 meters for two lanes. Meanwhile, actual conditions on the ground showed an average width of 16.4 meters, thus generally meeting the established standards. On the curve segment, the road width was planned at 18.45 meters, with actual conditions averaging 20.7 meters. This indicates that most curves meet the criteria, although some sections still require widening. The standard curve radius used is approximately 14.31 meters for a design speed of 20 km/h. The road's longitudinal gradient (grade) is planned to be a maximum of 8%, while field measurements indicate a maximum value of 6.3%, thus remaining within safe limits for transportation operations.

The recommended superelevation value is 4%. However, based on analysis, actual superelevation values in the field vary between 1.9% and 6.2%. Therefore, adjustments are needed for several curves with low superelevation values, primarily by increasing the height difference on the outside of the curve to meet the recommended standards. For the cross-slope on straight roads, the planned value is 4%, or 40 mm/m. Therefore, it is necessary to adjust the height difference between the center and edges of the road to increase the effectiveness of the drainage system and maintain the stability of the road surface.

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