Design of Geometric and Rigid Pavement Thickness on Jalan Lingkar Barat Sp. Sports Center - Bukit Sulap STA 0+100 - STA 7+583 Lubuklinggau City, South Sumatera Province

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ABSTRACT

Road construction is one of the government's efforts to facilitate the mobilization of the Indonesian people, both economically and socially. The purpose of this study was to design the geometric and rigid pavement thickness on Jalan Lingkar Barat SP Sports Center - Bukit Sulap STA 0+100 to STA 7+583 Lubuklinggau City, South Sumatra Province. The method used in this study was reviewing the vehicle volume, road terrain, and vehicle traffic load data. The analyses used were horizontal and vertical alignment calculations, and pavement thickness calculations. The generated design was referred to the standard criteria issued by the Indonesian Ministry of Public Works and Public Housing. The result from reviewing the vehicle volume, road terrain, and vehicle traffic load exhibited a total annual average daily traffic of 24404.06 SMP/day. Therefore, this road has been classified as Jalan Arteri Kelas I. From the alignment calculation, the road was designed with 11 bends: 4 Spiral-Circle-Spiral (SCS) bends, 4 Full-Circle (FC) bends, and 3 Spiral-Spiral (SS) bends, with an average speed recommended in the plan was 70 km/h. As from the pavement thickness calculation, the pavement designed was the rigid pavement with a thickness of 19 cm and a bottom layer of sand gravel mixture with a thickness of 15 cm.

Keywords: Road, Geometric Design, Rigid Pavement Thickness

1. INTRODUCTION

Roads have become a fundamental piece of human life due to their role in facilitating the distribution of goods and services, connecting one region to another, and improving the economy and living standards. In other words, adequate road infrastructure such as determine the road condition and develop the roads based on standard planning could be a booster of economic development.

To gain the best result and the most efficient way to develop a new road or enhance the capacity of an existing road, the government needs some effective method in the designing process, includes determining the road's geometric design. Some of the main things in a geometric design include sufficient road width, the number of bends made based on the road's geometric technical requirements (both vertical and horizontal alignment), and pavement thickness. All these factors are needed for vehicles with particular load and speed to pass through it safely and comfortably.

Lubuklinggau City is located on the highway between Palembang City and Bengkulu City. Therefore, this city is also known as an economic liaison between Bengkulu Province and South Sumatra Province. The growth of the economic activity in Lubuklinggau City and its surroundings induce the escalate of the need for good quality infrastructures and facilities development in this city. Hence, the government of Lubuklinggau City constructs some new roads such as the Jalan Lingkar Barat.

The Jalan Lingkar Barat is planned to be built from Petanang Village to Jogo Boyo Village, Lubuklinggau.
City (STA 0+100 to STA 7+583). The government believes this construction is the best alternative to reduce the traffic load on the Sumateran Highway that is full of private vehicles, public transportations, and cargo. Besides, the government also has a vision to evenly distribute the economic development of the people in Lubuklinggau, improving their living standards. Therefore, this construction is an agenda to complete the development of the south, north, and west area of Lubuklinggau City.

This study aims to assist the construction of Jalan Lingkar Barat. Specifically, the purposes of this study are: (1) to generated the geometric design of Jalan Lingkar Barat; and (2) to generated the design of rigid pavement thickness of Jalan Lingkar Barat.

2. RESEARCH METHOD

To generate the design of geometric and rigid pavement thickness on Jalan Lingkar Barat Sp. Sports Center–Bukit Sulap, the researchers collected some technical data. Furthermore, the researchers calculated the horizontal and vertical alignment to produce a road alignment design, the type, and the number of bends needed. Parallelly, the researchers conducted the calculation of the recommended rigid pavement thickness as well. The technical data referred include topographic maps, average daily traffic, subgrade CBR, rainfall data, and the cost per unit of works, tools, and materials for the road construction.

This study used four structural standards applicable in Indonesia as the references, namely (1) Cement Concrete Pavement Planning (Pd T-14-2003) from Bina Marga; (2) Geometric Design Procedures for Inter-City Roads issued by the Directorate General of Highways in 1997; (3) The 2017 Road Pavement Design Manual issued by the Ministry of Public Works and Housing of the Republic of Indonesia; and (4) The 2003 Cement Development Research Center of Department of Regional Infrastructure.

The flowchart in Figure 1 shows the process of pavement design generated from the collected data.

3. FINDINGS

3.1 Geometric Design

3.1.1 Technical Data of the Road Design

- Type of terrain: Hills
- Average rainfall: 306.77 mm/year
- Pavement design age: 20 years
- Velometer design: 70 km/hour

For The 2020 traffic load, the data is shown on Table 1 below.

Table 1. The 2020 traffic load data of Jalan Jalan Lingkar Barat Sp. Sport Center – Bukit Sulap

| No. | Vehicle Type | Characteristic | Total |
|-----|--------------|----------------|-------|
| 1   | Type 1       | MC             | 3235  |
| 2   | Type 2       | LV             | 953   |
| 3   | Type 3       | LV             | 1431  |
| 4   | Type 4       | LV             | 1116  |
| 5   | Type 5A      | LB             | 412   |
| 6   | Type 5B      | LB             | 154   |
| 7   | Type 6A      | MHV            | 781   |
| 8   | Type 6B      | MHV            | 488   |
| 9   | Type 7A      | LT             | 63    |
| 10  | Type 7B      | LT             | 1     |
| 11  | Type 7C      | LT             | 67    |
|     | **Total**    |                | **8701** |

3.1.2 Road Classification

The traffic load data shown in Table 1 above is used
2021 annual average daily traffic (Lalu Lintas Harian Rata-rata or LHR). Using \( n = 1 \) and the traffic growth rate \((i)\) based on the June 2017 revision of the SNI manual for pavement design = 4.83%, the following equation is obtained.

\[
LHR_{2021} = LHR \times (1 + i)^n
\]  

The results of the 2021 LHR calculation using Equations (1) are presented in Table 2 below.

**Table 2** Calculated Data of 2021 LHR on Jalan Lingkar Barat Sp. Sports Center - Bukit Sulap

| No. | Vehicle Type | Total emp | LHR (SMP) |
|-----|--------------|-----------|-----------|
| 1   | Type 2       | 953       | 1.00      | 953       |
| 2   | Type 3       | 1431      | 1.00      | 1431      |
| 3   | Type 4       | 1116      | 1.00      | 1116      |
| 4   | Type 5A      | 412       | 2.17      | 894.04    |
| 5   | Type 5B      | 154       | 1.81      | 278.74    |
| 6   | Type 6A      | 781       | 2.28      | 1780.68   |
| 7   | Type 6B      | 488       | 1.80      | 878.40    |
| 8   | Type 7A      | 63        | 2.11      | 132.93    |
| 9   | Type 7B      | 1         | 1.80      | 1.80      |
| 10  | Type 7C      | 67        | 2.13      | 142.71    |
|     | TOTAL        |           |           | 7609.30   |

The traffic growth rate in the beginning design is 4.83% and 20 years after it is opened (the pavement age design), it is assumed to be 6%. From this assumption, the LHR data obtained in 2021 is 7979.83 SMP/day and become 24404.06 SMP/day in 2041.

Based on the Geometric Design Procedures for Inter-City Roads No. 8/TBM/1997, Jalan Lingkar Barat Sp. Sports Center – Bukit Magic City Lubuk Linggau that has LHR > 20000 SMP/day is classified as Jalan Arteri Kelas I. From the road classification and LHR obtained, the generated design of the road’s width is 7 m with a shoulder width of 2 m on the left and right lanes.

**3.1.3 The Horizontal Alignment Calculation**

Based on topographic data and local road conditions, we generated 13 as shown in Table 3.

**Table 3** Generated Coordinate Points

| Point | X       | Y       |
|-------|---------|---------|
| A     | 9643200,948 | 260367,804 |
| P1    | 9642816,603  | 259895,517  |
| P2    | 9642509,189  | 259327,402  |
| P3    | 9642077,793  | 258943,394  |
| P4    | 9641760,718  | 258439,951  |
| P5    | 9641224,603  | 258277,047  |
| P6    | 9640699,584  | 258349,079  |
| P7    | 9640289,597  | 258805,136  |
| P8    | 9639824,891  | 259212,690  |
| P9    | 9639450,130  | 259755,551  |
| P10   | 9638825,933  | 260041,041  |
| P11   | 9638485,182  | 260661,072  |
| B     | 9638315,522  | 261320,800  |

From this data, the calculation of the road alignment shows the total road to be built is 7483.732 meters, with further data attached in Table 4 below.

**Table 4** Calculation Results of Road Alignment and Azimuth

| No. | Alignment | Azimuth (°) | Length (m) |
|-----|-----------|------------|------------|
| 1   | dA – P1   | 219,138    | 608,914    |
| 2   | P11 – P12 | 208,418    | 645,955    |
| 3   | P12 – P13 | 228,326    | 577,551    |
| 4   | P13 – P14 | 212,203    | 594,971    |
| 5   | P14 – P15 | 253,098    | 560,319    |
| 6   | P15 – P16 | 277,812    | 529,937    |
| 7   | P16 – P17 | 318,045    | 613,251    |
| 8   | P17 – P18 | 311,251    | 618,104    |
| 9   | P18 – P19 | 325,381    | 659,654    |
| 10  | P19 – P110| 294,578    | 686,386    |
| 11  | P110 – P11| 331,208    | 707,495    |
| 12  | P11 – B   | 345,578    | 681,194    |
|     | Total     |            | 7483,732   |

Forward, the calculation is carried out to find the bend’s type as shown in the Table 5 below.

**Table 5** Type of Bend

| Point | Bearing | Classification |
|-------|---------|----------------|
| PL1   | 10,720° | Full-Circle    |
| PL2   | 19,908° | Spiral-Circle-Spiral |
| PL3   | 16,123° | Spiral-Circle-Spiral |
| PL4   | 40,895° | Spiral-Spiral  |
| PL5   | 24,714° | Spiral-Circle-Spiral |
| PL6   | 40,233° | Spiral-Spiral  |
| PL7   | 6,794°  | Full-Circle    |
| PL8   | 14,130° | Full-Circle    |
| PL9   | 30,803° | Spiral-Circle-Spiral |
| PL10  | 36,630° | Spiral-Spiral  |
| PL11  | 14,370° | Full-Circle    |

The calculation results shows 11 bends, namely Full-Circle bends (four), Spiral-Circle-Spiral bends (four) and Spiral-Spiral bends (three).
3.1.4 The Vertical Alignment Calculation

From the vertical alignment calculation, the writers design a total of eight curves. Five of them are convex curves and the other three are concave curves. The vertical alignment calculation includes (1) slope design, (2) curve length, (3) curve stationing, and (4) vertical elevation.

3.1.4.1 Convex Vertical Curve

The Figure 8 below shows the sample of the road convex vertical curve.
a) Slope Design (A)

The slope design is 1.25%. It is calculated using the Equation 2.

\[ A = |g3 - g2| \]  

\( (2) \)

d) Vertical Elevation

The calculation of vertical elevation is summarized in Table 7 below.

**Table 7 Vertical Elevation**

| Station (STA) | Calculation                                      | Elevation (m) |
|---------------|--------------------------------------------------|---------------|
| PLV2          | Elev PPV2 - \( \frac{1}{2} L \times g^2 \) \( \frac{100}{100} \) | 142.878       |
| a             | Elev PPV2 - \( \frac{1}{4} L \times g^2 \) \( \frac{100 - y}{100} \) | 142.901       |
| PPV2          | Elev PPV2 - Ev                                  | 142.848       |
| b             | Elev PPV2 - \( \frac{1}{4} L \times g^2 \) \( \frac{100 - y}{100} \) | 142.718       |
| PTV2          | Elev PPV2 - \( \frac{1}{2} L \times g^2 \) \( \frac{100}{100} \) | 142.513       |

3.1.4.2 Concave Vertical Curve

The Figure 8 below shows the sample of the road convex vertical curve.

**Figure 8 Convex Vertical Curve Calculation**

To find the right vertical curve length, we consider some requirement such as the shape flexibility, drainage, and driver’s comfort. The maximum Lv we got from those three requirements is 50 meters. To check the minimum length, the equation below shows the detail.

\[ \text{Lv} = \frac{Jh^2}{405} = 97.5^2 = 23.472 \text{ m, 97.5 m (OK)} \]

\[ \text{Ev} = \frac{A \times \text{Lv}}{800} = \frac{1.25 \times 97.5}{800} = 0.152 \text{ m} \]

\[ X = \frac{1}{4} \text{Lv} = \frac{1}{4} 97.5 = 24.375 \text{ m} \]

\[ Y = \frac{\text{AX}^2}{200\text{Lv}} = \frac{1.25 \times 24.375^2}{200 \times 97.5} = 0.038 \text{ m} \]
c) Vertical Curve Length (Lv)

To find the right vertical curve length, we consider some requirement such as the shape flexibility, drainage and driver’s comfort. The maximum Lv we got from those three requirement is 160 meters. To check the minimum length, the equation below shows the detail.

\[ \text{Lv} = \frac{\text{Jh}}{405} = \frac{97.5}{405} = 0.2372 \text{ m}, \text{ 97.5 m (OK)} \]

\[ \text{Ev} = \frac{\text{A x Lv}}{800} = \frac{3.899 \times 160}{800} = 0.152 \text{ m} \]

\[ X = \frac{1}{4} \text{Lv} = \frac{1}{4} \times 60 = 15 \text{ m} \]

\[ Y = \frac{\text{AX}^2}{200L} = \frac{3.899 \times 40^2}{200 \times 160} = 0.195 \text{ m} \]

### 3.2 Calculation of Concrete Slab Thickness in Rigid Pavement Design

Type of work: Connected Concrete with Reinforcement

Type of shoulder: Sand-gravel mixture

Pavement age design: 20 years

JSKN design: 3.78 x 10^7

Safety factor: 1.1

Concrete flexural strength: 4.0 Mpa

Foundation layer: Sand-gravel mixture layer

Foundation layer thickness: 15 cm

CBR: 4.9%

Effective CBR: 33%

### Table 10 19 cm of Slab Thickness Calculation

| Axis | Design load of each axle (Kn) | Design load of each wheel | Repetion | Tension Factor and Erosion | Fatigue Analisy Repetion | Damage Percentage (%) | Erosion Analysis Repetion | Damage Percentage (%) |
|------|-------------------------------|--------------------------|----------|---------------------------|------------------------|-----------------------|------------------------|-----------------------|
| 1    | 2 (60)                        | 3                        | 4        | 5                         | 6                      | TT                    | 0                      | TT                    |
| STRT | 5 (50)                        | 27.5                     | 5798230.088 | TE = 1.03                 | TT                     | 0                    | TT                    |
| 4 (40)| 22                            | 7257079.646              | FRT = 0.258 | TT                       | 0                     | TT                    |
| 3 (30)| 16.5                          | 5259292.035              | FE = 2.26   | TT                       | 0                     | TT                    |
| 2 (20)| 11                            | 7257079.646              | TT         | 0                        | TT                    |
| 8 (80)| 22                            | 4534513.274              | TE = 1.63   | TT                       | 0                     | TT                    |
| STRG | 5 (50)                        | 13.75                    | 5259292.035 | FRT = 0.408               | TT                     | 0                    | TT                    |
| 14 (140)| 19.25                         | 1217256.637              | FRT = 0.333 | FE = 2.95                 | TT                     | 0                    | TT                    |
| Total |                               |                          |           |                           |                        | 0% < 100%             | 0% < 100%             |
Figure 12 below shows the transverse shrinkage joint using Dowel on connected concrete pavement without reinforced and the reinforcement of connected concrete pavement with reinforced.

![Figure 12](image)

**Figure 12** transverse shrinkage joint using Dowel on connected concrete pavement without reinforced

4. CONCLUSION

(1) The result from reviewing the vehicle volume, road terrain, and vehicle traffic load exhibits a total annual average daily traffic of 24404.06 SMP/day. Therefore, this road has been classified as Jalan Arteri Kelas I.

(2) From the alignment calculation, the road is designed with 11 bends: 4 Spiral-Circle-Spiral (SCS) bends, 4 Full-Circle (FC) bends, and 3 Spiral-Spiral (SS) bends with 8 vertical curve (5 convex curve and 3 concave curve).

(3) The average speed recommended in the plan is 70 km/h.

(4) From the pavement thickness calculation, the pavement designed is the rigid pavement with a thickness of 19 cm and a bottom layer of sand-gravel mixture with a thickness of 15 cm.

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