A Study Of Climbing Lane Road Planning On The Probolinggo-Grobogan-Wonorejo Road Segment

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Abstrak

Road planning is influenced by the road geometric condition and traffic volume as well as the soil structure condition. This research was conducted on the Probolinggo-Grobogan-Wonorejo road at Sta 127+050 to Sta 137+400 with hills and mountains dominated road access. Thus, there are many incline areas to be found. Coupled with the large volume of traffic, it will result in the accumulation of vehicles in the incline areas. Therefore, an additional lane (climbing lane) is needed in the incline areas. In this study, the geometric planning was carried out to determine the horizontal and vertical alignments and continued to determine the climbing lane area and pavement thickness in the climbing lane area with reference to the 1997 Intercity Road Geometric Planning Procedure (BINA MARGA, Tata Cara Perencanaan Geometrik Antar Kota 1997) and the 2017 Road Pavement Design Manual (BINA MARGA, Manual Desain Perkerasan Jalan 2017). From the results of this study, the geometric planning obtained was 3.5 wide lane using 2 lanes with 2 undivided directions and there were 12 bends with 7 S-S bends, 5 FC bends with flat terrain dominated by hills and mountains. In the flexible pavement design, the thickness of AC-WC = 5 cm, AC-BC = 6 cm, AC-BC Abs. premix = 22 cm, CTB = 15 cm, Class A Aggregate Foundation = 15cm, and the supporting layer with selected embankment = 35 cm. Meanwhile, the planning of the climbing lane obtained a total length of 2 km with details at 1 km long Sta 127+050 to Sta 128+050 which was located in a 5.161% incline area and at 1 km long Sta 131+200 to 132+200 which was located in a 4.23% incline area.

Keywords: climbing lane, flexible pavement, Road planning, road geometry

1. Introduction

1.1. Research Background

The access to transportation is one of the factors that support the economic growth and development in a certain area. A good transportation access, especially with land transportation, will help to mobilize the community to support their economic activities. The roads in East Java, especially in the southern region, have access roads that are predominantly mountainous and hilly. Thus, they are prone to accidents. Coupled with the many inclines, it will result in the accumulation of vehicles, especially heavy vehicles, and the road conditions will be getting worse and worse. This situation has made the traffic movement, both goods distribution and other road users, tends to move more slowly than in other areas. This will affect the economic development in the southern region of East Java. In regard to this problem, the author reviewed the geometric planning of the road and determined the hiking path and flexible pavement planning in the climbing lane area in accordance with the provisions of the 1997 Intercity Road Geometric Planning Procedure (BINA MARGA, Tata Cara Perencanaan Geometrik Antar Kota 1997) and the 2017 Road Pavement Design Manual (BINA MARGA, Manual Desain Perkerasan Jalan 2017) for road planning in the southern region of East Java on the Probolinggo-Grobogan-Wonorejo road section.

From these conditions, it can be concluded that the formulations of the problems are as follows:

1. How is the result of the geometric planning design (horizontal alignment and vertical alignment) in accordance with the provisions of the 1997 Intercity Road Geometric Planning Procedure (BINA MARGA, Tata Cara Perencanaan Geometrik Antar Kota 1997)?
2. How to plan a flexible pavement thickness with the 2017 Highways Standards (BINA MARGA, Manual Desain Perkerasan Jalan 2017)?
3. How to determine and plan the climbing lane at STA 127+050 to STA 137+400 with the provisions of the 1997 Intercity Road Geometric Planning Procedure (BINA MARGA, Tata Cara Perencanaan Geometrik Antar Kota 1997)?

1.2. Research Objectives

Based on the formulations of the problems, the research objectives are as follows:
1. Planning the geometric planning of the road which includes vertical and horizontal alignments in accordance with the provisions of the 1997 Intercity Road Geometric Planning Procedure.

2. Identifying the planning of flexible pavement thickness using the 2017 Highways Pavement Design Manual method.

3. Determining and planning the climbing lane at STA 127+050 to STA 137+400 in accordance with the provisions of the 1997 Intercity Road Geometric Planning Procedure.

2. Literature Review

2.1. Road Geometry

Road geometric planning is the planning of the physical form of the road that plans the complete route of the road. Thus, it can fulfill the purpose of the road which produces a comfortable and safe road infrastructure. The elements of road geometric planning are:

1. Horizontal alignment (situation/plan)
2. Vertical alignment (longitudinal cross section of the road)
3. Cross section of the road (cross section)

3) Stopping Visibility (Jh) and Overtaking Visibility (Jd).

Stopping visibility (Jh) and Overtaking Visibility (Jd) are the distances required for driver to stop the vehicle or overtake other vehicles safely.

\[ \frac{1}{2g f_p} \begin{pmatrix} \frac{V_R^3}{3.6} T \times \left(\frac{V_R}{3.6}\right)^2 + \end{pmatrix} \]

\[ Jd = d_1 + d_2 + d_3 + d_4 \]

\[ Jd = d_1 + d_2 + d_3 + d_4 \]

Description:

- \( Jh \): Minimum stopping visibility distance (m)
- \( V_R \): Designed velocity (km/h)
- \( T \): Response time is set to 2.5 seconds
- \( g \): Gravity acceleration = 9.8 m/s²
- \( f \): Friction coefficient = 0.35 – 0.55

\[ d_1 = 0.278 T (V_r - \frac{a - T_1}{2}) \]

\[ d_2 = 0.278 \times V_r \times T_2 \]

\[ d_3 = \text{between 30-100 m (adjusted to the designed velocity, $V_d$)} \]

\[ d_4 = \frac{2}{3} d_2 \]

\[ T_1 = 2.12 + 0.026 V_r \]

\[ T_2 = 6.56 + 0.048 V_r \]

\[ A = 2.052 + 0.0036 V_r \]

\[ m = \text{(between 10-15 km/h)} \]

4) Designed Velocity (Vr)

The designed velocity is the speed chosen for geometric road planning such as road slope planning, bends and others. It is also affected by road classification and road terrain.

<table>
<thead>
<tr>
<th>Function</th>
<th>Designed Velocity (Vd) (Km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteri</td>
<td>70-120 60-80 40-70</td>
</tr>
<tr>
<td>Kolektor</td>
<td>60-90 50-60 30-50</td>
</tr>
<tr>
<td>Lokal</td>
<td>40-70 30-50 20-30</td>
</tr>
</tbody>
</table>

(source: Dirjen Bina Marga, TPJAK 1997)

5) Horizontal Alignment

Horizontal alignment is the situation of the road or the projection of the road axis in the horizontal plane or commonly called the road alignment. The horizontal arch types are:

- Circular arc (FC) or Full Circle is a type of bend that only has a part of a circle. The formula used is as follows:

\[ Tc = R \frac{\tan \frac{1}{2} \Delta}{R} \]

\[ Ec = Tc \tan \frac{1}{4} \Delta \]

\[ Lc = \frac{\Delta_2 \pi R}{360} \]

\[ (3) \]

\[ (4) \]

\[ (5) \]

d. Transition Curve (Ls). The shape of the transition curve can be either parabolic or spiral (clothoid). With the transition curve, the bend uses the S-C-S bend shape.

4. Based on the maximum travel time of 3 seconds, to cross the transition curve. Then use the formula:
Based on the anticipated centrifugal force, the formula with Shortt modification was used as follows:
\[ L_s = \frac{v_R^3}{3.6} \]

Description: \( V_R = \) Designed velocity  
\( T = \) Travel time (3 seconds)

5. Based on the anticipated centrifugal force, the formula with Shortt modification was used as follows:
\[ L_s = 0.022 \frac{v_R^3}{R_c} - 2.727 \frac{R_c}{\omega} \]

Description: \( R_c = \) circle radius (m)  
\( e = \) superelevation  
\( C = \) change in velocity, (0.3-0.1 m/sec\(^3\)). 0.4 m/sec\(^3\) is recommended

6. Based on the realization of the slope change, we used the formula:
\[ L_s = \frac{(e_m-e_n) v_R}{3.6 R_c} \]

Description: \( e_m = \) maximum superelevation %  
\( e_n = \) normal superelevation %  
\( \omega = \) level of realization of the cross-road changes. (\( V_r \leq 70 \) km/h, \( V_r \geq 80 \) km/h, \( re \max. = 0.035 \) m/m/sec. \( V_r \geq 80 \) km/h, \( re \max. = 0.025 \) m/m/sec.)

With the formula used for the S-C-S bend as follows:
\[ Y_s = \frac{Ls^2}{6 R_c} \]
\[ X_s = Ls \left( \frac{1 - \frac{Ls^2}{40 R_c^2}}{40 R_c^2} \right) \]
\[ Oc = \Delta - 2 \Theta s \]
\[ \Theta s = \frac{90 Ls}{\pi R_c} \]
\[ k = Ls - \frac{k^2}{40 R_c^2} - R_c \sin \Theta s \]
\[ p = \frac{k^2}{6 R_c} - R_c \left( 1 - \cos \Theta s \right) \]
\[ E_s = (R_c + p) \tan \frac{\Delta}{2} - R_c \]
\[ T_s = (R_c + p) \tan \frac{\Delta}{2} + k \]
\[ L_c = \left( \frac{180}{(\Delta - 20 \omega)} \right) \pi R_c \]
\[ L_{tot} = L_c + 2 L_s \]

If the \( p \) value is calculated by the formula 19, then the bend determination is the FC bend
\[ p = \frac{k^2}{24 R_c} < 0.25 \ m \]

For the value of \( L_s \) = 1 m, then the value of \( p = p' \) and the value of \( k = k' \)

For the value of \( L_s \) = \( L_s \), then the value of \( p = p \times L_s \) and \( k = k \times L_s \)

E. Spiral curvature (S-S) is a curved shape consisting of an arc without an arc and a combination of 2 transitional arcs. The formula used for the S-S curve is as follows:
\[ L_c = 0 \ \text{dan} \ \Theta s = \frac{1}{2} \Delta \]
\[ L_s = \frac{\Theta s \pi R_c}{90} \]
\[ L_{tot} = 2 L_s \]

In determining \( \Theta s \), the formula (9) can be utilized. To determine the \( p, k, T_s, \) and \( E_s \) the formula is the same as the transition curve, namely the formulas (10)-(13).

6) Vertical Alignment

In the vertical alignment, an incline (positive slope) and descent (negative slope) was planned. Thus, for a combination of incline and descent, it produced a convex curve and a concave curve, besides the two curves there was a slope = 0 or flat.

a. Convex vertical curve

7. The length of \( L \), based on stopping visibility distance (Jh), used the following formulas:
\[ J_h < L, \ \text{so} : \ L = \frac{A \cdot J_h^2}{450} \]
\[ J_h < L, \ \text{so} : \ L = 2 J_h - \frac{450}{A} \]

8. The length of \( L \), based on overtaking visibility distance (Jd), used the following formulas:
\[ J_d < L, \ \text{so} : \ L = \frac{A \cdot J_d^2}{480} \]
\[ J_d < L, \ \text{so} : \ L = 2 J_d - \frac{480}{A} \]
Description:
\[ L = \text{Length of vertical arch (m)} \]
\[ A = \text{Grade difference (m)} \]
\[ J_h = \text{Stopping visibility distance (m)} \]
\[ J_d = \text{Overtaking visibility distance (m)} \]

b. Concave vertical curve

Concave vertical curve can use the following formulas:
\[ J_h < L, \text{so: } L = \frac{A - J_h^2}{120 + 3.5 J_h^2} \] \hspace{1cm} (27)
\[ J_h > L, \text{so: } L = 2 J_h - \frac{120 + 3.5 J_h^2}{A} \] \hspace{1cm} (28)

2.2. Climbing lane

The climbing lane is a lane intended for vehicles with heavy loads or other vehicles with slower speeds. Therefore, slower vehicles can be overtaken by other vehicles without having to use the lane in the opposite direction. The following are the provisions for the climbing lane based on the rules from the General Directorate of Highways’ 1997 Procedures for Geometric Planning for Intercity Roads (BINA MARGA, Tata Cara Perencanaan Geometrik Antar Kota 1997)

1. Climbing lanes must be provided on arterial or collector roads with a large, continuous slope and where the traffic volume is relatively dense.
2. If the critical length is exceeded, the road has a VLHR > 15.000 SMP/day, and the percentage of trucks > 15%.
3. The width of the climbing lane is the same as the width of the planned lane.
4. The climbing lane starts 30 meters from the beginning of the slope change with a 45 meters long slope and ends 50 meters after the top of the slope with a 45 meters long slope.
5. The minimum distance between 2 climbing lanes is 1.5 km.

2.3. Flexible Road Pavement

Flexible pavement is a type of road pavement which generally uses a mixture of asphalt surface layer and granular material as the undercoat. In this study, the flexible pavement planning used the 2017 Highways Pavement Design Manual Method (BINA MARGA, Manual Desain Perkerasan Jalan 2017).

1. Planned Design Life

Determination of the design life of the flexible pavement with reference to the 2017 Road Pavement Design Manual can be seen in the following table

<table>
<thead>
<tr>
<th>Type of Pavement</th>
<th>Elements of Pavement</th>
<th>Design Life (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible pavement</td>
<td>Asphalt layer and granular layer</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>Road foundation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>All pavements for areas where overlay is not possible, such as: urban roads, underpasses, bridges, tunnels, Cement Treated Based (CTB)</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>(source: Dirjen Bina Marga, MDP 2017)</td>
<td></td>
</tr>
</tbody>
</table>

2. Traffic Volume

The traffic volume was obtained from the results of previous traffic surveys or traffic surveys with a minimum duration of 7 x 24 hours referring to the traffic enumeration survey guidelines (Pd T-19-2004-B) or using equipment with the same approach.

3. Factor of Traffic Growth

Traffic growth during the design life was calculated by the cumulative growth factor with the following formula:
\[ R = \frac{(1+0.01 i)^{UR-1}}{0.01 i} \] \hspace{1cm} (30)

Description:
\[ R \quad : \text{Cumulative traffic growth multiplier} \]
\[ i \quad : \text{Annual traffic growth rate (%)} \]
\[ UR \quad : \text{Planned life (year)} \]
Table 3. Traffic Growth Rate Factors (i) (%)

<table>
<thead>
<tr>
<th></th>
<th>Jawa</th>
<th>Sumatera</th>
<th>Kalimantan</th>
<th>average at Indonesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteri dan Perkotaan</td>
<td>4.80</td>
<td>4.83</td>
<td>5.14</td>
<td>4.75</td>
</tr>
<tr>
<td>Kolektor</td>
<td>3.50</td>
<td>3.50</td>
<td>3.50</td>
<td>3.50</td>
</tr>
<tr>
<td>Road village</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

(source: General Directorate of Highways, MDP 2017)

1. Traffic on Planned Lane
   There are two factors that were taken into account in the planned lane traffic, including:
   a. Directional distribution factor (DD), generally taken a value of 0.5 for two-way roads.
   b. The lane distribution factor (DL). On roads with two or more lanes in one direction, the DL factor was used to adjust the cumulative load (ESA). The DL factor value can be seen in the following table.

   Table 4. Lane Distribution Factor (DL)

<table>
<thead>
<tr>
<th>Number of Lanes in Each Direction</th>
<th>Commercial Vehicles in Designed Lane (% of Commercial Vehicle Population)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
</tr>
<tr>
<td>4</td>
<td>50</td>
</tr>
</tbody>
</table>

   (source: General Directorate of Highways, MDP 2017)

2. Vehicle Damage Factor (VDF)
   The load equivalent factor is required as a traffic load conversion factor to standard load (ESA). The factor expressed in the comparison of the level of damage to the pavement caused by a certain vehicle trajectory is called the load equivalent factor. Axle load surveys should be carried out whenever possible, this is because a properly designed and executed axle load study or survey is the basis for reliable ESA calculations.

3. Cumulative Equivalent Standard Axle Load (CESAL)
   The cumulative sum of the designed traffic axle loads on the designed lane over the design life is called the Cumulative Equivalent Standard Axle Load (CESAL). 4 and 5-ranked CESAL in its calculation uses the VDF value for each commercial vehicle which is determined by the following formula:
   \[
   ESA_{TH-1} = \left( \sum LHR_{JK} \times VDF_{JK} \right) \times 365 \times DD \times DL \times R \quad \text{(31)}
   \]
   In which:
   - \( ESA_{TH-1} \) = Cumulative Equivalent Standard Axle Load in the first year.
   - \( LHR_{JK} \) = Average daily traffic for each type of commercial vehicle (unit of vehicle per day).
   - \( VDF_{JK} \) = Vehicle Damage Factor for each type of commercial vehicle.
   - DD = Directional distribution factor.
   - DL = Line distribution factor.
   - R = Cumulative traffic growth multiplier.

4. Desain perkerasan
   The pavement design is determined from the 4 or 5-ranked CESAL value (millions). In pavement design based on the lowest cost and traffic load, the plan was shown on several design charts based on the type of pavement. For flexible pavement, see the design chart-3 which consists of:
   a. Chart-3. Flexible Pavement Design with minimum cost option with CTB
   b. Design Chart - 3A. Flexible Pavement Design with HRS
   c. Chart 3B. Flexible Pavement Design – Asphalt with Grained Foundation (Alternative to Design Charts- 3 and 3A)
   d. Design Chart - 3C. Aggregate Foundation Layer Thickness Adjustment For CBR Subgrade 7 % (Only For Design Chart - 3B)

5. Road Foundation Design
   Insufficient soil bearing capacity requires special handling so that the sub-grade is able to support the pavement structure. However, sub-grades with a CBR value of 6% or more do not need for improvement. As for those with a CBR value of below 6%, a supporting layer is needed.

3. Research Method
   3.1. Research Location
   The research location of this final project is at the Probolinggo-Grobokan-Wonorejo Sta. 127+050 – Sta. 137+400 which is located in the border area of Lumajang Regency, East Java.
3.2. Research Method

This study, entitled "A Study of Climbing Lane Road Planning on the Probolinggo-Grobogan-Wonorejo Road Section", examined road planning which included road geometric planning which planned the climbing lane area as well as the road structure planning which planned the flexible pavement of the road, especially in the climbing lane areas.

In this study, the method used for road geometric planning was the General Directorate of Highways’ 1997 Method of Intercity Geometric Planning Procedures (BINA MARGA, Tata Cara Perencanaan Geometrik Antar Kota 1997) and the 2017 Road Pavement Design Manual method for the flexible pavement (BINA MARGA, Manual Desain Perkerasan Jalan 2017).

3.3. Research Flow Chart

![Figure 3.1. Research Flow Chart](image-url)
4. Results And Discussion

4.1. Road Geometric Planning

<table>
<thead>
<tr>
<th>Bend</th>
<th>STA</th>
<th>$\Delta$ (Bend Angle)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Decimal</td>
</tr>
<tr>
<td>P1</td>
<td>0+131.755</td>
<td>18.283</td>
</tr>
<tr>
<td>P2</td>
<td>0+102.283</td>
<td>10.45</td>
</tr>
<tr>
<td>P3</td>
<td>0+479.900</td>
<td>15.229</td>
</tr>
<tr>
<td>P4</td>
<td>1+251.678</td>
<td>6.955</td>
</tr>
<tr>
<td>P5</td>
<td>1+621.587</td>
<td>3.001</td>
</tr>
<tr>
<td>P6</td>
<td>3+961.226</td>
<td>8.123</td>
</tr>
<tr>
<td>P7</td>
<td>4+208.601</td>
<td>22.759</td>
</tr>
<tr>
<td>P8</td>
<td>4+502.581</td>
<td>14.537</td>
</tr>
<tr>
<td>P9</td>
<td>4+585.259</td>
<td>19.963</td>
</tr>
<tr>
<td>P10</td>
<td>4+918.385</td>
<td>29.823</td>
</tr>
<tr>
<td>P11</td>
<td>5+180.444</td>
<td>3.260</td>
</tr>
<tr>
<td>P12</td>
<td>8+559.733</td>
<td>26.339</td>
</tr>
</tbody>
</table>

Tabel 5. Road Trace Bend Angle

Gambar 2. Road Trace (Source: calculation results, 2021)

1. Horizontal Alignment Planning

   The following is the calculation of the bend at P1 where the road terrain was categorized as hilly roads and the speed of Vr 70 km/hour was taken (table 1). The calculation data were as follows:

   a. Road function and terrain : hilly road arteries
   b. $e_{\text{max}}$ dan $e_{\text{normal}}$ : 10% and 3%
   c. c (velocity change) : 0.4 m/s
   d. D (road width) : 3.5 meters (2 lanes 2 ways)
   e. Vr (designed velocity) : 70 km/h

   Solution:
   f. Friction Coefficient ($f$)  
      $f = -0.00655 \times \text{Vr} + 0.192 = 0.140$
   g. Minimum Radius ($R_{\text{min}}$)  
      $R_{\text{min}} = \frac{Vr^2}{127 (e_{\text{max}} + f)} = \frac{6400}{127 (0.1 + 0.140)} = 209.97$
   h. (then, the R used was : 250 m > 209.97)
   i. Superelevation Control  
      $e = \frac{Vr^2}{127 (R_{\text{min}})} - f = \frac{6400}{127 (250)} - 0.14 = 0.062$
   j. (then, the e used was = 6.2 % $\leq$ $e_{\text{max}}$ = 10%)
   k. Determinant of Transitional Curvature
1. max. travel time (T=3 det)  
\[ L_s = \frac{V_r}{3.6} - T = 66.67 \text{ m} \]
2. anticipating centrifugal force  
\[ L_s = 0.022 \left( \frac{V_r^2}{R_c e} \right) - 2.727 \left( \frac{V_r x e}{e} \right) = 79.06 \text{ m} \]
3. level of achievement grade  
\[ L_s = \frac{(\delta m - \delta n)}{3.6} V_r = \frac{(0.062 - 0.03)}{3.6} \times 0.03 \]
\[ = 26.4 \]

(a) from all these formulas, the greatest Ls values was taken which was 79.06 m)

a. Spiral Bend Angle (\( \theta S \))
\[ \theta S = 90 \times \frac{L_s}{R_c} \]
\[ = 79.06 \times \frac{90}{250} = 9.1^\circ \]
b. Circle Curved Angle (\( \theta C \))
\[ \theta C = \Delta - 2 \theta S = 18.283 - (2 \times 9.1) = 0.16^\circ \]
c. Circle Arch Length (\( L_c \))
\[ L_c = \frac{(\theta C - 2 \theta S)}{180} \pi \times R_c = \frac{0.16}{180} \times 3.14 \times 250 = 0.68 \text{ m} \]
d. Distance between point ST and point TC (\( X_s \))
\[ X_s = L_s \left( 1 - \frac{L_s}{L_s + \frac{40 R_c}{6 R_c}} \right) = 76.06 \left( 1 - \frac{76.06}{76.06 + 250} \right) = 78.86 \text{ m} \]
e. SC Perpendicular Distance on the Curve (\( Y_s \))
\[ Y_s = L_s \left( 1 - \frac{76.06}{6.250} \right) = 4.17 \text{ m} \]
f. Tangent Shift to the Spiral (\( P \))
\[ P = L_s - R_c \left( 1 - \cos \theta S \right) = 4.17 - 250 \left( 1 - \cos 9.1 \right) = 1.05 \text{ m} \]
g. P Abscissa to the Tangent of the Spiral (\( k \))
\[ k = X_s + (R_c \sin \theta S) = 78.86 + (250 \cdot \sin 9.1) = 39.48 \text{ m} \]

Based on the calculation, the value of p = 1.05 > 0.25. Thus, the S-C-S or S-S calculation model was used.

Requirements: If \( L_c > 25 \text{ m} \), then S-C-S is used.
If \( L_c < 25 \text{ m} \), then S-S is used.

The S-S model was used because \( L_c = 0.68 < 25 \text{ m} \), with the calculation of Ts and Es as follows

1) \( Ts = (R_c + p) \tan \frac{1}{2} (\Delta + k) = (251.05)0.16 + 39.48 = 79.87 \text{ m} \)
2) \( Es = \frac{(R_c + p)}{\cos \frac{1}{2} \Delta} - R_c = (254.27) - 250 = 4.27 \text{ m} \)
3) \( Lt (the length of L S-S) \)
\[ L_{tot} = 2 L_s = 2(79.057) = 158.11 \text{ m} \]

For other calculations, see the following table

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**Table 6. Calculation of Horizontal Alignment**

<table>
<thead>
<tr>
<th>PI</th>
<th>( \psi )</th>
<th>Vr</th>
<th>fmax</th>
<th>Rmin</th>
<th>Rc</th>
<th>Lc</th>
<th>Type of bend</th>
<th>DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>18.283</td>
<td>9.064</td>
<td>80</td>
<td>0.140</td>
<td>209.974</td>
<td>250</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>2</td>
<td>10.450</td>
<td>10.344</td>
<td>70</td>
<td>0.147</td>
<td>156.522</td>
<td>200</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>3</td>
<td>15.229</td>
<td>2.864</td>
<td>60</td>
<td>0.153</td>
<td>112.041</td>
<td>500</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>4</td>
<td>6.955</td>
<td>1.790</td>
<td>90</td>
<td>0.134</td>
<td>273.146</td>
<td>1200</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>5</td>
<td>3.001</td>
<td>1.313</td>
<td>110</td>
<td>0.123</td>
<td>432.089</td>
<td>2000</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>6</td>
<td>8.123</td>
<td>2.028</td>
<td>65</td>
<td>0.137</td>
<td>246.235</td>
<td>1000</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>7</td>
<td>22.795</td>
<td>12.322</td>
<td>60</td>
<td>0.153</td>
<td>112.041</td>
<td>150</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>8</td>
<td>14.537</td>
<td>16.056</td>
<td>50</td>
<td>0.160</td>
<td>75.857</td>
<td>100</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>9</td>
<td>15.963</td>
<td>26.918</td>
<td>40</td>
<td>0.166</td>
<td>47.928</td>
<td>50</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>10</td>
<td>29.823</td>
<td>15.516</td>
<td>60</td>
<td>0.153</td>
<td>112.041</td>
<td>150</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>11</td>
<td>3.267</td>
<td>2.028</td>
<td>85</td>
<td>0.137</td>
<td>240.295</td>
<td>1000</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
<tr>
<td>12</td>
<td>26.339</td>
<td>10.344</td>
<td>70</td>
<td>0.147</td>
<td>156.522</td>
<td>200</td>
<td>P &gt; 0.25, Lc &lt; 25</td>
<td>S-S</td>
</tr>
</tbody>
</table>

---

2. Vertical Alignment

The data and conditions for PV1 are as follows:

a. \( Vr = 80 \text{ km/jam} \)

b. Based on the stopping visibility (\( Jh \)) = 120 m (formula 1)

c. \( g1 = -3.528 \% \)

d. \( g2 = -0.771 \% \)

e. \( A = g1 - g2 = -2.758 \% \) (cekung)

---

3. Calculation of L length

1. Based on the stopping visibility

\[ J_h < L, maka : L = \frac{A \cdot J_h^2}{120 + 3.5J_h} \]
\[ = \frac{2.758 \cdot 120^2}{120 + 3.5 \cdot 120} \]
\[ = 114.667 \text{ meter (memenuhi)} \]

\[ J_h > L, maka : L = 2J_h - \frac{120 + 3.5J_h}{A} \]
\[ = 2 \cdot 120 - \frac{120 \cdot 3.5 \cdot 120}{2.758} \]
\[ = 114.419 \text{ meter (memenuhi)} \]
2. Based on the visual form of vertical curver (length for comfort)

\[ L = \frac{A_v^2}{380} = \frac{2.758 \times 80^2}{380} = 72.421 \text{ meter} \]

(L = 300 meters was taken with economic considerations following the exiting of the previous road to avoid excessive excavation)

4. Calculation of \( Ev \) (height distance of the point of intersection of the PPV to the vertical curve).

\[ Ev = A_v \times \frac{L}{\text{380}} = \frac{2.758 \times 300}{800} = 1.034 \text{ meters} \]

5. Calculation of STA and the vertical arch elevation.

\[
\begin{align*}
\text{STA di PPV} &= 128+073.716 \\
\text{Elevasi PPV} &= \text{Elv point of intersection of the PPV + } Ev \\
&= 207.012 + 1.034 \\
&= 208.046
\end{align*}
\]

\[
\begin{align*}
\text{STA di PLV} &= \text{STA PPV} - \left( \frac{L}{2} \right) \\
&= (128+073.716) - 150 \\
&= 127+923.716 \\
\text{Elevasi PLV} &= \text{Elv point of intersection of the PPV + } (L/2 \times g_1) \\
&= 207.012 + 150 \times 3.259% \\
&= 212.305
\end{align*}
\]

\[
\begin{align*}
\text{STA di PTV} &= \text{STA PPV} + \left( \frac{L}{2} \right) \\
&= (128+073.716) + 150 \\
&= 128+223.716 \\
\text{Elv. PTV} &= \text{Elv point of intersection of the PVV - } (L/2 \times g_1) \\
&= 207.012 - 150 \times 0.77% \\
&= 205.856
\end{align*}
\]

For other calculations, see the following table: Table 6. Calculation of Vertical Alignment

<table>
<thead>
<tr>
<th>vertical curve</th>
<th>( V_d )</th>
<th>( A (g1-g2) )</th>
<th>type of vertical curve</th>
<th>stop (( \text{sr} )</th>
<th>precede (( \text{pr} )</th>
<th>L used (( m ))</th>
<th>Ev (( m ))</th>
<th>PPV</th>
<th>PTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>PV1</td>
<td>80</td>
<td>2.758</td>
<td>cembung</td>
<td>120</td>
<td>550</td>
<td>300</td>
<td>1.03425</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PV2</td>
<td>70</td>
<td>1.892</td>
<td>cembung</td>
<td>97.5</td>
<td>450</td>
<td>50</td>
<td>0.11825</td>
<td>128+679.552</td>
<td>128+704.552</td>
</tr>
<tr>
<td>PV3</td>
<td>70</td>
<td>-3.232</td>
<td>cembung</td>
<td>97.5</td>
<td>450</td>
<td>100</td>
<td>0.404</td>
<td>128+839.559</td>
<td>128+889.559</td>
</tr>
<tr>
<td>PV4</td>
<td>70</td>
<td>3.619</td>
<td>cembung</td>
<td>97.5</td>
<td>450</td>
<td>100</td>
<td>0.452375</td>
<td>129+556.076</td>
<td>129+606.076</td>
</tr>
<tr>
<td>PV5</td>
<td>90</td>
<td>-3.035</td>
<td>cembung</td>
<td>147.5</td>
<td>610</td>
<td>400</td>
<td>1.5175</td>
<td>127+706.010</td>
<td>129+390.010</td>
</tr>
<tr>
<td>PV6</td>
<td>90</td>
<td>1.311</td>
<td>cembung</td>
<td>147.5</td>
<td>610</td>
<td>100</td>
<td>0.163875</td>
<td>130+430.813</td>
<td>130+480.813</td>
</tr>
<tr>
<td>PV7</td>
<td>90</td>
<td>-2.742</td>
<td>cembung</td>
<td>147.5</td>
<td>610</td>
<td>300</td>
<td>1.02825</td>
<td>130+610.962</td>
<td>130+760.962</td>
</tr>
<tr>
<td>PV8</td>
<td>90</td>
<td>4.323</td>
<td>cembung</td>
<td>120</td>
<td>550</td>
<td>250</td>
<td>1.3509375</td>
<td>131+203.999</td>
<td>131+348.999</td>
</tr>
<tr>
<td>PV9</td>
<td>90</td>
<td>1.311</td>
<td>cembung</td>
<td>120</td>
<td>550</td>
<td>300</td>
<td>0.49125</td>
<td>131+694.706</td>
<td>131+834.706</td>
</tr>
<tr>
<td>PV10</td>
<td>90</td>
<td>-6.214</td>
<td>cembung</td>
<td>120</td>
<td>550</td>
<td>500</td>
<td>3.88375</td>
<td>132+712.126</td>
<td>132+842.126</td>
</tr>
<tr>
<td>PV11</td>
<td>70</td>
<td>6.926</td>
<td>cembung</td>
<td>97.5</td>
<td>450</td>
<td>200</td>
<td>1.7315</td>
<td>132+625.577</td>
<td>132+722.577</td>
</tr>
<tr>
<td>PV12</td>
<td>70</td>
<td>-1.763</td>
<td>cembung</td>
<td>97.5</td>
<td>450</td>
<td>100</td>
<td>0.220375</td>
<td>133+163.781</td>
<td>133+243.781</td>
</tr>
<tr>
<td>PV13</td>
<td>60</td>
<td>0.99</td>
<td>cembung</td>
<td>75</td>
<td>350</td>
<td>100</td>
<td>0.13275</td>
<td>133+464.173</td>
<td>133+514.173</td>
</tr>
<tr>
<td>PV14</td>
<td>60</td>
<td>-2.572</td>
<td>cembung</td>
<td>75</td>
<td>350</td>
<td>250</td>
<td>0.643</td>
<td>133+775.074</td>
<td>133+875.074</td>
</tr>
<tr>
<td>PV15</td>
<td>60</td>
<td>-0.861</td>
<td>cembung</td>
<td>75</td>
<td>350</td>
<td>100</td>
<td>0.107625</td>
<td>134+174.423</td>
<td>134+244.423</td>
</tr>
<tr>
<td>PV16</td>
<td>50</td>
<td>0.897</td>
<td>cembung</td>
<td>55</td>
<td>250</td>
<td>100</td>
<td>0.057125</td>
<td>134+719.688</td>
<td>134+769.688</td>
</tr>
<tr>
<td>PV17</td>
<td>50</td>
<td>1.021</td>
<td>cembung</td>
<td>55</td>
<td>250</td>
<td>100</td>
<td>0.127625</td>
<td>136+382.987</td>
<td>135+432.987</td>
</tr>
<tr>
<td>PV18</td>
<td>40</td>
<td>-1.088</td>
<td>cembung</td>
<td>40</td>
<td>200</td>
<td>100</td>
<td>0.136</td>
<td>136+528.085</td>
<td>135+578.085</td>
</tr>
<tr>
<td>PV19</td>
<td>60</td>
<td>-0.426</td>
<td>cembung</td>
<td>75</td>
<td>350</td>
<td>100</td>
<td>0.05325</td>
<td>136+648.855</td>
<td>136+798.855</td>
</tr>
<tr>
<td>PV20</td>
<td>70</td>
<td>2.568</td>
<td>cembung</td>
<td>450</td>
<td>200</td>
<td>100</td>
<td>0.321</td>
<td>136+622.988</td>
<td>136+739.988</td>
</tr>
<tr>
<td>PV21</td>
<td>70</td>
<td>-3.836</td>
<td>cembung</td>
<td>450</td>
<td>100</td>
<td>150</td>
<td>0.71925</td>
<td>136+656.851</td>
<td>136+791.851</td>
</tr>
<tr>
<td>PV22</td>
<td>80</td>
<td>3.849</td>
<td>cembung</td>
<td>120</td>
<td>550</td>
<td>200</td>
<td>0.94225</td>
<td>137+053.981</td>
<td>137+153.981</td>
</tr>
</tbody>
</table>

For the calculation results: Type of vertical curve: cembung = convex; cekung = concave.
4.2. Climbing Lane Planning

According to the data obtained on the planned roads starting from STA 127+050 to STA 137+400 with a length of 10,350 meters, the vehicle volume was > 15000 Smp/day (the LHR data obtained is the data in 2020 where a 7 x 12 hours survey was conducted; the average number of vehicles was 23,513 smp/day and the volume percentage of trucks was more than 15%). Therefore, a climbing lane was needed on this route.

The climbing lane was planned with a total length of 2 km, specifically at STA 127 + 050 to 128 + 050 with a length of 1 km in the incline area of 5.161% and 4.523% (this value was obtained in the continuous incline area which exceeds the critical length). For STA 131+200 to 12+200 it was planned with a length of 1 km in the incline area of 4.23% and 3.91% (this value was obtained in the continuous incline area which exceeds the critical length).

4.3. Flexible pavement thickness design

The thickness of the flexible pavement was planned by following the 2017 Road Pavement Design Manual reference. The planning was carried out on the climbing lane roads at Sta 127+050 to Sta 137+500 with a design life of 20 years for the flexible pavement and a design life of 40 years for the pavement foundation. The LHR data and solid VDF values, see Table 7 for calculating the CESAL values.

1. Calculating the Cumulative Equivalent Standar Axle Load (CESAL)

In planning this road section, the CESA5 calculation was used for the flexible pavement layers with a design life of 20 years due to the large volume of vehicles. The traffic growth rate was 4.8% in the 2020 LHR data, the first year after the opening for traffic in 2022 with a direction distribution (DD) of 0.5 and a lane distribution (DL) of 1 for each type of vehicle. The CESAL calculation value can be seen in the following table.

Table 7. Calculation of CESA5 for 20 Years Life Pavement (2022-2042)

<table>
<thead>
<tr>
<th>transportation type</th>
<th>average daily traffic (2arah) 2020</th>
<th>average daily traffic (2arah) 2022</th>
<th>VDF5 Actual (java island, Indonesia)</th>
<th>ESA5 (’22-’42)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5b Bus besar</td>
<td>521.00</td>
<td>572.22</td>
<td>1.0</td>
<td>3,380,904.74</td>
</tr>
<tr>
<td>6a Truck 2 As (4 Roda)</td>
<td>325.00</td>
<td>356.95</td>
<td>0.5</td>
<td>1,054,504.84</td>
</tr>
<tr>
<td>66l.2 Truck sedan. 2 As (6 Roda) ringan</td>
<td>1,256.00</td>
<td>1,397.47</td>
<td>9.2</td>
<td>74,984,703.39</td>
</tr>
<tr>
<td>662.2 Truck sedan. 2 As (6 Roda) berat</td>
<td>1,852.00</td>
<td>2,034.06</td>
<td>9.2</td>
<td>110,566,616.78</td>
</tr>
<tr>
<td>7a1 Truck berat 3 As (tricon)</td>
<td>899.00</td>
<td>987.38</td>
<td>14.4</td>
<td>84,007,371.25</td>
</tr>
<tr>
<td>7a2 Truck berat 3 As (tricon)</td>
<td>1,007.00</td>
<td>1,105.99</td>
<td>19.0</td>
<td>124,159,021.93</td>
</tr>
<tr>
<td>7b Truck gandeng/semi trailer tunggal 4 gandar</td>
<td>215.00</td>
<td>236.14</td>
<td>18.2</td>
<td>25,392,476.49</td>
</tr>
<tr>
<td>7c1 Truck Tandem</td>
<td>160.00</td>
<td>175.73</td>
<td>19.8</td>
<td>20,557,977.39</td>
</tr>
</tbody>
</table>

1. Determining the Thickness of the Pavement Used

From the calculation results, the number of CESAS5 for the pavement layers with 20 years life (2022-2042) was 444,103,576.80. In this plan, asphalt concrete pavement with cement treated base (CTB) was used because this road section serves medium and heavy traffic. Thus, the CTB foundation layer was chosen. The thickness of the asphalt layer and CTB can be seen in the “ROAD PAVEMENT DESIGN MANUAL (REVISION 2017)” guideline Number 02/M/BM/2017 chapter 7 page 12 chart-3, column F5 (Flexible Pavement Design with minimum cost option with CTB)

From the CESAS5 calculation and the adjustment of the chart-3 table of Flexible Pavement Design with the minimum cost option with CTB, the followings were obtained:

a. AC-WC thickness = 50 mm
b. AC-BC thickness = 60 mm
c. AC-BC, Premixed Abs = 220 mm
d. CTB thickness = 150 mm
e. Grade A aggregate foundation thickness = 150 mm

2. Planning the Support Layer Thickness (Foundation Design)

In planning the road foundation, it was planned that the design life was 40 years according to Table 2. The Design Life of the New Road Pavement. This figure was adjusted to the 2017 MDP guidelines. The CBR data was obtained from the results of subgrade testing using the DCP (Dynamic cone Penetrometer) tool at a distance of 1,200 meters on the planned climbing lane, namely at STA 127+050 to 128+050 at an incline area of 5.161% and STA 131+200 to 132+200 at an incline area of 4.27%. The following is the CBR data obtained on the planned road sections.
From the corrected CBR calculation, it can be concluded that:

<table>
<thead>
<tr>
<th>NO.</th>
<th>KM</th>
<th>CBR Mean</th>
<th>CBR Factor</th>
<th>Measurement Factor</th>
<th>Corrected CBR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>127+250</td>
<td>3.43</td>
<td>0.80</td>
<td>1.00</td>
<td>2.74</td>
</tr>
<tr>
<td>2</td>
<td>127+450</td>
<td>3.23</td>
<td>0.80</td>
<td>1.00</td>
<td>2.58</td>
</tr>
<tr>
<td>3</td>
<td>127+650</td>
<td>3.03</td>
<td>0.80</td>
<td>1.00</td>
<td>2.42</td>
</tr>
<tr>
<td>4</td>
<td>127+850</td>
<td>3.54</td>
<td>0.80</td>
<td>1.00</td>
<td>2.83</td>
</tr>
<tr>
<td>5</td>
<td>128+050</td>
<td>3.74</td>
<td>0.80</td>
<td>1.00</td>
<td>2.99</td>
</tr>
<tr>
<td>6</td>
<td>131+200</td>
<td>3.64</td>
<td>0.80</td>
<td>1.00</td>
<td>2.91</td>
</tr>
<tr>
<td>7</td>
<td>131+400</td>
<td>3.14</td>
<td>0.80</td>
<td>1.00</td>
<td>2.51</td>
</tr>
<tr>
<td>8</td>
<td>131+600</td>
<td>3.64</td>
<td>0.80</td>
<td>1.00</td>
<td>2.07</td>
</tr>
<tr>
<td>9</td>
<td>131+800</td>
<td>3.54</td>
<td>0.80</td>
<td>1.00</td>
<td>2.83</td>
</tr>
<tr>
<td>10</td>
<td>132+000</td>
<td>3.66</td>
<td>0.80</td>
<td>1.00</td>
<td>2.93</td>
</tr>
</tbody>
</table>

The CBR characteristic value was 2.51%, which indicated that the soil strength class was SG2.5, where a support layer was necessary. The thickness of the foundation layer can be seen in the “ROAD PAPER DESIGN MANUAL (REVISION 2017) guideline Number 02/M/BM/2017” chapter 6 page 15: Design Chart - 2: Minimum Road Foundation Design. The obtained thickness of the supporting layer (foundation design) was 350 mm.

5. Conclusions

Based on the results of the study for road planning on the Probolinggo-Grobogan-Wonorejo section at Sta 127+050 to Sta 137+400, the designs obtained was as follows:

1. In the geometric planning, the road was planned to use 2 undivided 2-way lanes (2/2UD) with a width of each lane of 3.5 m with the classification of flat and hilly roads. In the horizontal alignment, there were 12 bends; 7 bends with the spiral-spiral type and 5 bends with the full circle type.
2. In the flexible pavement design referring to the 2017 MDP, the design obtained was in accordance to Chart-3 Flexible Pavement Design with the minimum cost option with CTB with the following thickness: AC-WC = 5 cm, AC-BC = 6 cm, AC-BC Abs. premix = 22 cm, CTB = 15 cm, Class A Aggregate Foundation = 15 cm, and the supporting layer with selected embankment = 35 cm.
3. In the planning of the climbing lane, the total length of the climbing lane was 2 km which is located at 1 km long Sta 127+050 to Sta 128+050 located in an incline area of 5.161% and at 1 km long Sta 131+200 to 132+200 located in an incline area of 4.23%.

References