Geometric and Pavement Design of Probolingg – Banyuwangi Toll Road Section 1 (Probolinggo – Besuki)

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ARTICLE INFO

Article Information
Article Received: 2022-07-28
Article Revised: 2022-10-19
Article Accepted:

Keywords
Bina Marga, Civil 3D, Toll Road, Geometric Planning, Vertical and Horizontal Alignment Planning, Rigid Pavement Design.

ABSTRACT

A toll road is a project the government considers as a solution that can decrease congestion so it can become a source of income for the state treasury. One of the Mega Projects of Toll Road currently being worked on is the Trans Java Toll Road Project. One of the toll roads that are part of the Trans Java Toll Road Project is the Probolinggo – Banyuwangi Toll Road, commonly called the Probowangi Toll Road. The Probolinggo – Banyuwangi Toll Road or Probowangi Toll Road is a 171.5 km long toll road that stretches from Probolinggo to Banyuwangi. The construction of the Probolinggo – Banyuwangi toll road itself is intended as an alternative connecting road between the two cities. The old road is Pantura Road which takes 4-5 hours, whereas if people pass the Probolinggo – Banyuwangi toll road, the travel time is only 2 hours. It is expected that there will be an increase in the distribution of goods and services to support the economic growth of the two cities in line with the increase in the trade and industrial sectors of Probolinggo Regency and the increasing number of tourists in Banyuwangi Regency. The calculation results in the Probolinggo – Banyuwangi Toll Road section 1 planning in this study shows that the 46.6 km alignment has 20 Points of Intersection bends and 37 Vertical Points of Intersection. The thickness of the rigid concrete pavement was 350 mm, the layer of Lean Mix Concrete was 100 mm, the drainage layer was 150 mm, and the cement stabilization was 300 mm. The total draft budget obtained was IDR 2.892.506.355.107,06.

INTRODUCTION

Roads are one of the supporting infrastructures in an area that can function as a means to develop existing potential and facilitate the movement of people and the distribution of goods from villages to cities and vice versa. Roads are divided into several types. One of them is the toll road. A toll road itself is a public road where if you go through it and users have to pay a toll fee. According to Law 38 of 2004, toll roads are public roads that are part of a road network system whose users are required to pay tolls. According to this understanding, the construction of public roads or toll roads must be carried out properly and in accordance with standards that can be used optimally for toll road users [1]. Therefore, the central government wants to build a toll road that can be utilized by the people in the area.

S One of the Mega Projects of Toll Road currently being worked on is the Trans Java Toll Road Project. This mega project of Trans Java Toll Road will be a link between Anyer and Banyuwangi. This project is worth IDR 46.77 trillion and was initiated in the 1990s. One of the main functions of the construction of the Trans Java Toll Road is to accelerate economic growth and improve public services. The construction of the Trans Java Toll Road will pass through 4 provinces and have 15 toll roads. This toll road will merge with the 7 previously operating toll roads, namely Jakarta Anyer, Toll Road in Jakarta, Jakarta Outer Ring Road, Jakarta Cikampek, Cirebon Kanci, Semarang Ring Road, and Surabaya Gempol [2].

One of the toll roads that are part of the Trans Java Toll Road Project is the Probolinggo – Banyuwangi Toll Road, commonly called the Probowangi Toll Road. The Probolinggo – Banyuwangi Toll Road or Probowangi Toll Road is a 171.5 km long toll road that stretches from Probolinggo to Banyuwangi, which will later be divided into three sections. These sections are Section 1 Probolinggo – Besuki, Section 2 Besuki – Bajulmati (Situbondo Regency), and Section 3 Bajulmati – Ketapang (Banyuwangi Regency. This toll road will be integrated later with the Ketapang port, which is the connecting port between Java and Bali, as well as being the final segment route in the construction of the Trans Java Toll Road.

The construction of the Probolinggo – Banyuwangi toll road itself is intended as an alternative connecting road between the two cities. The existing road takes 4-5 hours, while if people pass the Probolinggo – Banyuwangi toll road, the travel time is only 2 hours.

Thus, it is expected that it will improve the distribution of goods and services to support economic growth between the two cities.

LITERATURE REVIEW

A. Alignment

Road alignment consists of connected straight lines or the axis of the road on a topographic map. Alignment is used as a reference line to form the curve of the road to the pavement and as a determination of the height of the subgrade. Road alignment is planned with many alternatives, and will choose one of the best alternatives. The basic things that become a reference in road alignment planning are as follows:

1. Road length
2. Number of bends
3. Number of intersections
4. Amount of land acquisitions
5. Number of settlements
6. The size of the excavation and embankment

B. Geometric Planning

Geometric road planning is part of road planning focused on planning the physical form to fulfill the road's basic function, namely providing optimum service to traffic flow and maximizing the ratio of implementation cost utilization rate [3]. Meanwhile, geometric planning aims to produce geometric road conditions that can provide maximum service for road users by prioritizing safety, comfort, and smooth traffic [4].

C. Road Pavement

Road Pavement Design Manual regulations (2017) are used as a reference in planning road pavements. Road pavement is divided into three types, namely flexible pavement, rigid pavement, and composite pavement. The type of pavement used in this journal is Rigid Pavement [5].

D. Drainage

Drainage planning is one of the things that must be considered in geometric planning. Planning is useful for drainage or water disposal on roads when it rains. The main data as the drainage planning basis is rainfall data which can be taken from rain stations in the nearest study locations.

E. Signs and Markings

Drainage planning is one of the things that must be considered in geometric planning. Planning is useful for drainage or water disposal on roads when it rains. The main data as the drainage planning basis is rainfall data which can be taken from rain stations in the nearest study locations.

F. Excavation and Embankment

Cut and fill work or excavation and embankment work is always encountered in geometric road planning, especially in areas with steep topography. The basic work of cut and fill is to use a topographic map equipped with contour lines.

METHODOLOGY

A. Problem Identification Stage

The problem identification stage was carried out by searching for news or articles regarding the government's plans for toll road construction. After finding the title for this study, a gap analysis was carried out to find the problem formulation used in conducting this study.

B. Preparation Stage

The preparatory stage is the process of preparing the things required to facilitate the implementation of the following work. Some things in the preparation stage are as follows:

a. Find the information from relevant agencies about the data required.
b. Prepare necessary letters, such as proposals and cover letters for the designated agency.
c. Survey for the primary data needed in planning.
d. Find, collect, and study all activities that support the making of this activity.

C. Library and Literature Study

Library and literature studies were carried out by reading sources or regulations that underlie the topic and assisting in working on the theories related to the topics in this study. The source could be in the form of existing study books on more or less the same topic, regulations or planning standards issued by government agencies, or pages downloaded from the internet.

D. Trip Assignment Analysis

In the geometric planning of the Probolinggo – Banyuwangi Toll Road, data is required to help carry out this study. Data can be obtained from related parties, such as owners, contractors, or consultants.

The technical data required include as follows:

1. Topographic Map
2. Rainfall Data
3. Average Daily Traffic Data
4. CBR and HSPK Data

RESULTS AND DISCUSSIONS

A. Alignment Selection

The method used was Multi Criteria Analysis method using a zero-one matrix of the three alignments that have been made and weighted with criteria including length of the alignment, the volume of excavation and embankment, number of bends, number of intersections, area of settlements and land acquisition. Based on the calculations, it was found that the alignment with the highest value was alternative alignment number 2 (Light Blue).

B. Geometric Planning

1) *Horizontal Alignment*

1. Road Classification

Road classification data:

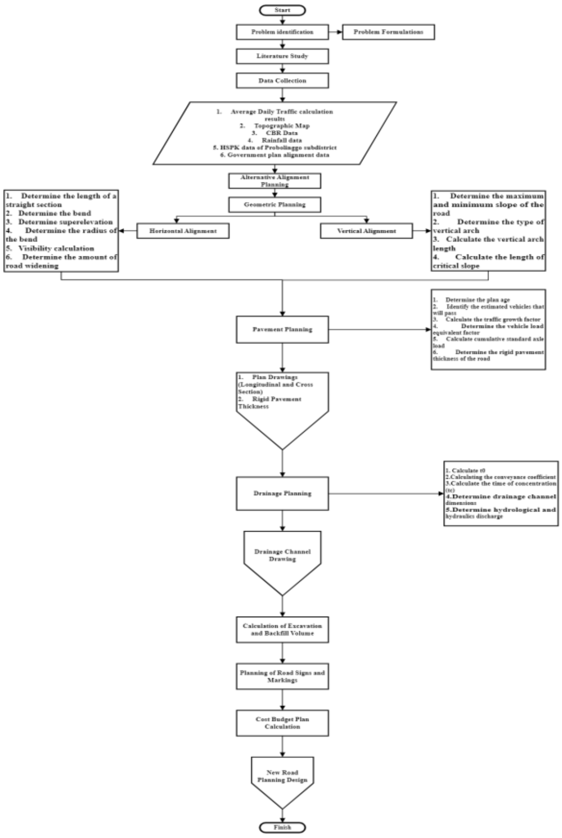

Figure 1. Flowchart

Figure 2 Planned Alignment and Alternatives

Table 1. Azimuth Angle Calculation

NO PI	*DX*	*DY*	*Azimuth (f)*	*Bend angle (Δ)*
Start	0,00	0,00	-	-
PI1	2634,5	-816,7	72,8	25,7
PI2	2492,2	371,7	81,5	17,4
PI3	1122,9	544,7	64,1	26,3
PI4	1482,7	-11,4	89,6	41,0
PI5	1433,8	1226,6	49,5	20,3
PI6	1808,8	667,0	69,8	20,3
PI7	2679,3	-1,6	90,0	21,7
PI8	1235,2	-491,9	68,3	53,7
PI9	1319,8	825,2	58,0	12,7
PI10	2199,2	2180,8	45,2	23,0
PI 11	775,5	1893,2	22,3	32,4
PI 12	4296,2	3044,8	54,7	24,9
PI 13	2536,9	465,8	79,6	23,5
PI 14	1479,9	-344,8	76,9	10,0
PI 15	1954,4	-835,2	66,9	36,4
PI 16	1532,3	360,2	76,8	38,3
PI 17	2283,7	-1068,4	64,9	4,0
PI 18	1461,6	-813,5	60,9	16,3
PI 19	1990,4	-451,0	77,2	34,8
PI 20	531,2	215,1	68,0	20,8

Table 2. Superelevation Calculations

PI	*e+f*	*f(D) f2*	*e*
PI1	0,131	0,059	7%
PI2	0,131	0,059	7%
PI3	0,131	0,059	7%
PI4	0,131	0,059	7%
PI5	0,131	0,059	7%
PI6	0,131	0,059	7%
PI7	0,131	0,059	7%
PI8	0,131	0,059	7%
PI9	0,131	0,059	7%
PI10	0,131	0,059	7%
PI 11	0,131	0,059	7%
PI 12	0,131	0,059	7%
PI 13	0,131	0,059	7%
PI 14	0,131	0,059	7%
PI 15	0,131	0,059	7%
PI 16	0,131	0,059	7%
PI 17	0,131	0,059	7%
PI 18	0,131	0,059	7%
PI 19	0,131	0,059	7%
PI 20	0,131	0,059	7%

a. Road Class : Toll Road
b. Road Field : Mountains
c. Road Type : 4/2 D
d. Road Width : 7 m
e. Planned Age : 40 years

2. Azimuth Angle Value

Azimuth angle calculation to determine the magnitude of the bend angle.

PI 2 : X = 764389,072
Y = 9135720,898

PI 3 : X = 765511,956
Y = 9136265,612

Furthermore is to find the differences between the X and Y points of 2 PI.

$\Delta X = X_{PI\,3} - X_{PI\,2}$
$= 765511{,}956 - 764389{,}072$
$= 1122{,}884$

$\Delta Y = Y_{PI\,3} - Y_{PI\,2}$
$= 9136265{,}612 - 9135720{,}898$
$= 544{,}714$

If already obtained the value of the difference between X and Y, thus it can calculate the road length from point PI 2 – PI 3.

$d = \sqrt{\Delta X^2 + \Delta Y^2}$
$= \sqrt{1122{,}884 + 544{,}714^2}$
$= 1248{,}031$ m

Defining alpha angle:

PI 3 is located in quadrant I because ΔX and ΔY are positive (+), then the alpha calculation is carried out using the quadrant I formula:

$\alpha = arc\tan\left(\frac{\Delta X}{\Delta Y}\right)$
$= arc\tan\left(\frac{1122{,}884}{544{,}714}\right)$
$= arc\tan(2{,}061419)$
$= 64{,}12185°$

Defining azimuth angle:

Because PI 3 is located in quadrant I, then azimuth $\alpha = 64{,}12185°$

Bend angle calculation:

$\Delta = \alpha_4 - \alpha_3$
$= 90{,}440 - 64{,}121 = 26{,}3°$

Azimuth angle calculation can be seen in Table 1.

3. Bend Radius Calculation

Before calculating the minimum bend radius, the maximum skid resistance is calculated first.

Table 3. Transition Curve Calculations

PI	*Lrr (m)*	*Lr (m)*	*Ls min (m)*	*Ls plan (m)*
PI1	66,72	85,99	29,72	100
PI2	66,72	85,99	29,72	100
PI3	66,72	85,99	29,72	100
PI4	66,72	85,99	29,72	100
PI5	66,72	85,99	29,72	100
PI6	66,72	85,99	29,72	100
PI7	66,72	85,99	29,72	100
PI8	66,72	85,99	29,72	100
PI9	66,72	85,99	29,72	100
PI10	66,72	85,99	29,72	100
PI 11	66,72	85,99	29,72	100
PI 12	66,72	85,99	29,72	100
PI 13	66,72	85,99	29,72	100
PI 14	66,72	85,99	29,72	100
PI 15	66,72	85,99	29,72	100
PI 16	66,72	85,99	29,72	100
PI 17	66,72	85,99	29,72	100
PI 18	66,72	85,99	29,72	100
PI 19	66,72	85,99	29,72	100
PI 20	66,72	85,99	29,72	100

Table 4. Transition Curve Parameter Calculations

PI	*Teta s*	*Lc*	*Yc*	*Xc*	*Ts*	*L*
PI1	4,77	169,2	2,78	99,93	187,05	369,20
PI2	4,77	82,2	2,78	99,93	141,88	282,16
PI3	4,77	175,6	2,78	99,93	190,43	375,61
PI4	4,77	329,2	2,78	99,93	274,51	529,23
PI5	4,77	112,6	2,78	99,93	157,56	312,64
PI6	4,77	112,3	2,78	99,93	157,40	312,34
PI7	4,77	127,0	2,78	99,93	165,00	327,01
PI8	4,77	462,7	2,78	99,93	354,27	662,65
PI9	4,77	33,5	2,78	99,93	117,07	233,45
PI10	4,77	140,5	2,78	99,93	172,02	340,50
PI 11	4,77	239,3	2,78	99,93	224,51	439,29
PI 12	4,77	161,0	2,78	99,93	182,73	360,98
PI 13	4,77	146,3	2,78	99,93	175,04	346,29
PI 14	4,77	5,0	2,78	99,93	102,67	204,97
PI 15	4,77	280,8	2,78	99,93	247,29	480,83
PI 16	4,77	301,1	2,78	99,93	258,58	501,06
PI 17	4,77	-57,8	2,78	99,93	71,11	142,18
PI 18	4,77	71,0	2,78	99,93	136,19	271,03
PI 19	4,77	264,6	2,78	99,93	238,30	464,55
PI 20	4,77	117,7	2,78	99,93	160,19	317,74

V_D = 100 km/hour > 80 km/hour, then the formula is as follows:

f_{max} = -0,00125 x V_D + 0,24
= -0,00125 x 100 + 0,24
= 0,115

$$R\ min = \frac{VD^2}{127\ (f\ max + e\ max)}$$
$$= \frac{100^2}{127\ (0{,}115+0{,}008)}$$
= 403,795 m

R plan to use = 600 m

4. Superelevation Calculations

Superelevation calculations refer to AASHTO.

Vr = 80% x Vd
= 80% x 100 km/hour
= 80 km/hour

(e+f) = (emax + fmax) x D/Dmaks
= (8% + 0,115) x 2,38/3,54
= 0,131

$$f(D) = Mo \times \left(\frac{D\max - D}{D\max - Dp}\right)^2 + h + (D - Dp) \times tg\ \alpha 1$$
= 0,05916

e = (e+f) – f(D)
= 0,131-0,05
= 7%

Superelevation calculations can be seen in Table 2.

Table 5. Curve Type Calculations

PVI	*G1*	*G2*	*A*	*Curve Types*
PVI 1	-0,86%	0,76%	-1,62%	Concave
PVI 2	0,76%	-0,82%	1,58%	Convex
PVI 3	-0,82%	0,96%	-1,78%	Concave
PVI 4	0,96%	-1,33%	2,29%	Convex
PVI 5	-1,33%	0,69%	-2,02%	Concave
PVI 6	0,69%	-0,94%	1,63%	Convex
PVI 7	-0,94%	0,82%	-0,12%	Concave
PVI 8	0,82%	-0,93%	-0,11%	Concave
PVI 9	-0,93%	0,78%	-1,71%	Concave
PVI 10	0,78%	-1,53%	2,31%	Convex
PVI 11	-1,53%	1,14%	-2,67%	Concave
PVI 12	1,14%	1,12%	0,01%	Convex
PVI 13	1,12%	-0,75%	1,87%	Convex
PVI 14	-0,75%	1,27%	0,52%	Convex
PVI 15	1,27%	-0,82%	0,45%	Convex
PVI 16	-0,82%	1,35%	-2,17%	Concave
PVI 17	1,35%	-0,76%	2,11%	Convex
PVI 18	-0,76%	0,88%	-1,65%	Concave
PVI 19	0,88%	-1,29%	2,18%	Convex
PVI 20	-1,29%	-1,51%	0,22%	Convex
PVI 21	-1,51%	0,53%	-2,04%	Concave
PVI 22	0,53%	2,43%	-1,90%	Concave
PVI 23	2,43%	2,39%	0,05%	Convex
PVI 24	2,39%	-1,66%	4,05%	Convex
PVI 25	-1,66%	-1,24%	-0,42%	Concave
PVI 26	-1,24%	-1,52%	0,28%	Convex
PVI 27	-1,52%	4,34%	-5,86%	Concave
PVI 28	4,34%	-1,34%	5,68%	Convex
PVI 29	-1,34%	0,87%	-2,22%	Concave
PVI 30	0,87%	-0,85%	1,72%	Convex
PVI 31	-0,85%	0,81%	-1,65%	Concave
PVI 32	0,81%	-0,95%	1,76%	Convex
PVI 33	-0,95%	1,38%	-2,33%	Concave
PVI 34	1,38%	-1,43%	2,82%	Convex
PVI 35	-1,43%	1,27%	-2,70%	Concave
PVI 36	1,27%	-1,48%	2,75%	Convex
PVI 37	-1,48%	2,44%	-3,92%	Concave

5. Transition Curve Calculations

Transition curve calculation refer to Bina Marga 2021 [6].

a. Based on Rotation Rate

Lrr = $(0{,}278(e_1\text{-}e_2)V)/r$
= (0,278/(8%-2%)100)/2,5%
= 66,72 m

b. Based on Relative Slope

Lr = $((w\ n_1 \times ed)/\Delta) \times b_w$
= ((3,5x 2 x 7%)/0,44%) x 1,5
= 85,99 m

c. Minimum Transition Curve

$$Ls\ min = \frac{0{,}0214 \times V^3}{R \times 1{,}2}$$
$$= \frac{0{,}0214 \times 100^3}{600 \times 1{,}2}$$
= 29,72 m

Thus, the Ls used is 100 m. Transition curve calculations can be seen in Table 3.

6. Curve Parameter Calculation

7. The calculation of the horizontal curve parameter uses the Spiral Circle Spiral (SCS) parameter which refers to Bina Marga 1997 [6].

$$\theta_S = \frac{Ls}{2R} x \frac{360}{2\pi} = \frac{Ls\ x\ 90}{\pi\ x\ R} = \frac{100\ x\ 90}{\pi\ x\ 600}$$
= 4,77 °

$$Lc = \frac{\Delta_C}{180} x\ \pi\ x\ R = \frac{16{,}769}{180} \times \pi \times 600$$
= 175,607 m

$$Yc = \frac{Ls^2}{6\ R} = \frac{100^2}{6 \times 600}$$

Table 6. LHR Calculations

Vehicle Class	*I*	*LHR 2022 (lvu/hour)*	*LHR 2025 (lvu/hour)*	*LHR 2062 (lvu/hour)*
2	4,80%	1403	1615	9152
3	4,80%	235	271	1533
4	4,80%	286	330	1866
5A	4,80%	3	4	20
5B	4,80%	56	65	366
6A	4,80%	351	405	2290
6B	4,80%	1057	1217	6895
7A	4,80%	556	640	3627
7B	4,80%	55	64	359
7C	4,80%	71	82	464

= 2,77 m

$$Xc = Ls - \frac{Ls^3}{40\,R^2} = 100 - \frac{100^2}{40 \times 600^2}$$

= 99,93 m

TS = (R + p) tg $\frac{1}{2}$ Δ + k

= (600 + 0,695) tan $\frac{1}{2}$ 26,318 + 49,98 = 190,43 m

L = Lc + (2xLs)

= 175,60 + (2 x 100) = 375,60 m

Transition curve parameter calculation can be seen in Table 4.

2) *Vertical Alignment*

Slope calculation using the following formula:

$$G1 = \frac{Elevation\ PVI\ 2 - Elevation\ PVI\ 3}{L}$$

$$= \frac{23-30{,}52}{915} \times 100\% = -0{,}82\%$$

As for determining the type of curves are as as follows:

A = G1-G2

= -0,82% - 0,96%

= -1,78% < 0% (Concave)

Because the type of curve is a concave curve, the length of the curve is as follows:

a. L Minimum

Lmin = 0,6 x Vr = 0,6 x 100 = 60 m

b. Stopping Sight Distance

$$S_S = (0{,}278 \times 100 \times 2{,}5) + \frac{100^2}{254[\left(\frac{3{,}4}{9{,}81}\right) - 1{,}78\%]}$$

= 190 m

c. S<L

$$L = \frac{A \times S^2}{120 + 3{,}5\,S} = \frac{1{,}78 \times 178^2}{120 + (3{,}5 \times 178)} = 75{,}58 \text{ m}$$

178 m < 75,58 m (Not OK)

d. S>L

$$L = 2\,S - \frac{120 + (3{,}5 \times S)}{A}$$

$$= 2 \times 178 - \frac{120 + (3{,}5 \times 178)}{1{,}78} = -61{,}99 \text{ m}$$

178 m > -61,99 m (OK)

e. Driver Comfort Factor

$$L = \frac{A \times V^2}{395} = \frac{1{,}78 \times 100^2}{395} = 45 \text{ m}$$

L use = 60 m (Greatest)

Curve type calculations can be seen in Table 5

C. Road Pavement Thickness Design

1) Plan Age

The plan age for the construction of the Probolinggo – Banyuwangi Toll Road is 40 years due to the use of a rigid pavement. With the opening year of 2025, the plan age is forecasted to be 2062.

Table 7. CESAL Calculation

Vehicle Types	*VDF 5*	*i*	*R*	*DL*	*DD*	*CESA 2043*
2	0	4,80%	40,377	80%	0,5	0
3	0	4,80%	40,377	80%	0,5	0
4	0	4,80%	40,377	80%	0,5	0
5A	0,2	4,80%	40,377	80%	0,5	11555
5B	1	4,80%	40,377	80%	0,5	1093522
6A	0,8	4,80%	40,377	80%	0,5	6642011
6B	1,7	4,80%	40,377	80%	0,5	22368976
7A	64,4	4,80%	40,377	80%	0,5	445846582
7B	90,4	4,80%	40,377	80%	0,5	61657417
7C	93,7	4,80%	40,377	80%	0,5	81970395
Total CESAL						619590458

a. LHR 2025 = LHR Class 2 (2022) x $(1+i)^n$

= 1403 x $(1+4{,}80\%)^3$

= 1615 lvu/hour

b. LHR 2062 = LHR Class 2 (2022) x $(1+i)^n$

= 1403 x $(1+4{,}80\%)^{40}$

= 9152 lvu/hour

LHR calculations can be seen in Table 6.

2) *Trip Assignment*

Trip Assignment functions to determine and estimate the vehicle movement volume from the existing road to the planned road, namely the Probolinggo – Banyuwangi Toll Road. Trip Assignment analysis in this study used the Smock Method. After analyzing with the Davidson method, the total movement was 77%. The following is an example of class 2 calculations.

a. LHR 2025 = LHR Class 2 x $(1+i)^n$ x Movement

= 1403 x $(1+4{,}80\%)^2$ x 77%

= 1238,8 vehicles/day

3) *The Age of Traffic Plan*

The CESAL calculation in this study refers to the 2017 Road Pavement Design Manual (RPDM) [8] and used class 5B.

$$R = \frac{(1+0{,}01\,i)^{UR}-1}{0{,}01\,i} = \frac{(1+0{,}01 \times 4{,}8\%)^{40}-1}{0{,}01 \times 4{,}8\%} = 40{,}376$$

CESAL= (LHR 2025 x R x VDF 5 x DD x DL x 365)

= (186 x 40,37 x 1 x 80% x 0,5 x 365)

= 1093522

CESAL calculations can be seen in Table 7.

4) *Pavement Thickness*

Pavement structure layers were determined based on the total cumulative standard axle load. The reference used in determining pavement thickness was Pd T-14-2003 [7].

Total CESA	= 619590458 = 619 x 10^6
Pavement thickness	= R5
Concrete slab thickness	= 350 mm
LMC foundation layer	= 100 mm
Drainage layer	= 150 mm
Cement stabilization	= 300 mm

D. Design of Road Signs and Markings

Signs on the geometric road planning are useful for giving directions to the driver. The following is the calculation of the guide signs based on the number of bends, namely 20 bends. Directional signs installed are instructions as far as 150 m before the bend [8].

Number of road signs = Number of bends x Number of directions

= 20 x 2 = 40 pieces

Based on the regulation of the Minister of Transportation of the Republic of Indonesia, number PM

34 of 2014 in article 17, for continuous markings, use a straight line with a minimum width of 10 cm to a maximum of 15 cm [9].

Whereas for dashed markings based on the regulation of the Minister of Transportation of the Republic of Indonesia number PM 34 of 2014 in article 18, for dashed markings use a dotted line with a minimum width of 10 cm to a maximum of 12 cm [9].

E. Earthworks

Calculation of the volume of excavation and embankment in the Probolinggo – Banyuwangi Toll Road design was obtained using the Civil 3D software tool, which is displayed every STA per 500 m. The following is the total volume of excavation and embankment.

Excavation = 4763332 m^3
Embankment = 7711964 m^3
Difference = 2948632 m^3

F. Drainage Design

The design of drainage channels refers to SNI 03-3424-1994 Road Surface Drainage Planning Procedures [10]. Whereas the rainfall data used as a reference was rainfall data from the Dusun Krajan, Probolinggo Regency. The following is an example of the drainage channel design results at STA 1+492:

Discharge (Q) Hydrology = 0,7849 m^3/det
Discharge (Q) Hydraulics = 0,9652 m^3/det
A channel = 0,888 m^2
B plan = 1,3 m
H plan = 0,7 m
h water = 0,577 m
h total = 1,24 m
Slope (i) = 0,001

G. Budget Plan

Based on calculations on the construction of the Probolinggo – Banyuwangi toll road section 1 (Probolinggo – Besuki) required a cost of IDR 2.892.506.355.107,06 (Two Trillion and Eight Hundred Ninety-Two Billion and Five Hundred Six Million and Three Hundred Fifty-Five Thousand and One Hundred Seven Rupiah).

CONCLUSIONS

The calculations and analysis of the Study of Geometric and Pavement Design of the Probolinggo – Banyuwangi Toll Road Section 1 can be concluded as follows:

1. Geometric Road Planning

This toll road has a total PI (Point of Intersection) of horizontal alignment of 20 pieces. Meanwhile, the vertical alignment has 37 Vertical Points of Intersection (PVI). Further road details can be seen as follows:

a. Road Length = 46600 m
b. Road Type = 4/2 D
c. 1 Lane Width = 7 m (3,5 m x 2)
d. Outer Roadside Width = 2,5 m
e. Inside Roadside Width = 1,5 m
f. Median Road Width = 3 m
g. Plan Speed = 100 km/hour
h. Bend Radius = 600 m
i. Bend Type = SCS (*Spiral-Circle-Spiral*)
j. Convex Curve = 19 pieces
k. Concave Curve = 18 pieces
l. Excavation Volume = 4763332 m^3
m. Embankment Volume = 7711964 m^3

2. Road Pavement Planning

The results of road pavement planning based on the calculation of the cumulative amount of axle loads are as follows:

a. Concrete Slab Thickness = 350 mm
b. LMC Foundation Layer = 100 mm
c. Drainage Layer = 150 mm
d. Cement Stabilization = 300 mm
e. Tie Bars Diameter = 19 mm
f. Spoke Diameter = 36 mm

3. Drainage Planning

The results of planning and calculating typical dimensions of drainage channels are as follows:

a. Channel 1
B = 0,9 m
H = 0,4 m
H channel = 0,9 m
b. Channel 2
B = 1,1 m
H = 0,6 m
H channel = 1,09 m
c. Channel 3
B = 1,2 m
H = 0,6 m
H channel = 1,17 m
d. Channel 4
B = 1,3 m
H = 0,7 m
H channel = 1,22 m
e. Channel 5
B = 1,4 m
H = 0,7 m
H channel = 1,33 m
f. Channel 6
B = 1,5 m
H = 0,8 m
H channel = 1,37 m
g. Channel 7
B = 1,6 m
H = 0,8 m
H channel = 1,45 m
h. Channel 8
B = 1,8 m
H = 0,9 m
H channel = 1,55 m

4. Budget Plan

Based on the results of the budget plan for the Probolinggo – Banyuwangi toll road section 1 was IDR 2.892.506.355.107,06.

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