



THE DESIGN OF ALIGNMENT HORIZONTAL USING INDONESIA HIGHWAY DESIGN STANDARD: A CASE OF JALAN BABAT – TAPEN, EAST JAVA

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ABSTRACT

Horizontal alignment is included in the aspect of the geometric design of the road. Jalan Babat – Tapen in Jombang, East Java, is planned to have three horizontal alignments. This design aims to connect Jalan Babat and Jalan Tapen to shorten the travel time for the surrounding community's needs. This research uses the Bina Marga method, which refers to the Highway Design Standard of Indonesia 2021. First, road traffic data is obtained from the google earth application. The global mapper is then processed in AutoCAD to determine the coordinates of the road trace and the location of horizontal alignment. Then the data obtained is processed by referring to the Bina Marga method to design horizontal alignment. Jalan Tapen – Babat is a Secondary SJJ (Urban Road), Secondary Collector, and medium road, and the minor type of road 2/2 is not separate (TT). It has a flat terrain in design with a planned speed of 40 km / h. Three horizontal alignments with Spiral-Circle-Spiral (SCS) type, the first horizontal alignment is at STA 0+700 – 0+864, the second horizontal alignment is at STA 1+383 – 1+558, and the third horizontal alignment is at STA 2+132 – 2+304.

INTRODUCTION

Well-functioning infrastructure, such as road and rail networks, is one of the keys to the country's economic growth. Initially, humans-built roads only prioritizing one function, connecting one area to another. Then it develops by paying attention to the structure of the road and creating an effective route. At this time, building roads must use environmentally friendly materials and remember the previous aspects. Therefore, sustainable urban road planning should include financial, environmental, and social elements (Karlsson, Kalantari, Mörtberg, Olofsson, & Lyon, 2017); (Qiao & Shang, 2019).

The road is a land transportation infrastructure that includes all parts of the road, including complementary buildings and equipment intended for traffic, which is at ground level, above ground level, below ground and water level, as well as above water level, except railways, lorry roads, and cable roads. Roads must be designed to meet various needs, and construction implementation must be sustainable to protect biodiversity. Creating a new path is undoubtedly a challenging thing. Road planning is very complex in this context, based on several aspects and

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variables that must be considered. A geometric road design must adhere to the concept of being effective, efficient, economical, safe, and environmentally friendly. Its purpose is to guarantee the safety and comfort of road users (Ministry of Public Works, 2011); (Laschi, et al., 2019); (Aguiar, et al., 2021); (Ministry of Public Works, 2011); (Plessen, Bernardini, Esen, & Bemporad, 2017).

In the era of rapid technological development, an *engineer* can design a project using existing technology. Autocad Civil 3D is a software civil and professional engineers use to plan and design road projects. However, technology is just a tool (Mandal, Pawade, Sandel, & Infrastructure, 2019). An engineer must master a fundamental science to be applied to technology. Designing uses a manual method referring to Bina Marga about the Highway Design Standard of Indonesia 2021. Ways of geometric design of roads that include design criteria, general provisions, geometric technical provisions of roads, and geometric design procedures of roads, in designing horizontal linemen of roads, vertical paragraphs of roads, cross-sections of roads, and coordination of horizontal and vertical paragraphs of roads, for Highways, Medium Roads, Minor Roads, and Freeways, both serving Intercity traffic and inner city traffic (Ministry of PUPR, Director General of Highways, 2021).

Many people in Ploso District, Jombang Regency, East Java, make a living as farmers with agricultural products such as tobacco, corn, and crops. Along with developing agricultural products in the Ploso area, Jombang, East Java, must be balanced with the development of infrastructure in the area. One is road construction to facilitate access through the community to activities from one area to another.

The purpose of the geometric design of this road is to connect Babat road and Tapen road with an effective and safe route following the Highway Design Standard of Indonesia in 2021. With a road length of 2,467 km from Sta 0+000 – 2+467, it will focus on the horizontal curves of the road. Therefore, it does not include a cross-section of the road and the coordination of horizontal and vertical bends of the road.

LITERATURE REVIEW

Road Geometric Design

Traffic accidents can result in injury and even death. Although one million people die yearly on the road, traffic accidents can be predicted and prevented. Therefore, the road is expected to guarantee user comfort and safety, allow efficient traffic operation, and at the same time, attract the minimum possible cost of construction and maintenance. Getting a comfortable and safe road for road users has its stages (Wedajo, Quezon, & Mohammed, 2017); (Álvarez, Fernández, Gordaliza, Mansilla, & Molinero, (2020); (Raji, Zava, Jirgba, & Osunkunle, 2017).

Several factors can affect the behavior of road users, and geometric roads are one of them. On roads with sharp turns, drivers need time to prepare their cars to pass these corners. One of the good geometric designs of the road is that on the longitudinal cut of a road, there is a horizontal alignment. The driver does not feel like passing through the horizontal alignment because the radius of the horizontal alignment is large (Bobermin, Silva, & Ferreira, 2021).

Geometric road design is part of road planning. Geometric road design has several provisions and procedures for producing road designs that meet the design criteria. The

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engineering design of toll roads in the mountains emphasizes inspection to ensure safety because the main goal in the geometric design of roads is safety. The geometric design of the road determines the road class, the plan speed, the road slope, the width of the road, lanes, and paths according to the applicable provisions following its primary purpose. The calculation of bends, or what is commonly called horizontal or vertical alignment, is also included in the geometric design of the road (Li, Ding, & Zhong, 2019).

Bina Marga Method

To plan a road, the local government refers to the regulations that apply in a country. For example, road design in India refers to IRC (Indian Road Congress), and America's refers to AASHTO (American Association of State Highway and Transportation Officials). Of course, countries have their policies and particular criteria because each country is different. For example, America has a snowy season, but Indonesia does not (Kumar & Vyas, 2021).

The most widely used method in Indonesia is Bina Marga. Because the Directorate General of Wildlife Development oversees all road projects. The Directorate General of Wildlife Development is under the Ministry of Public Works and Public Housing. Bina Marga issued a circular regarding the Highway Design Standard of Indonesia 2021, a reference for designing a road because it has been made based on previous regulations (Faisal, Ahlan, Mutiawati, & Rozi, 2021).

The geometric design of the road must follow Bina Marga standards. The standard of Bina marga is to use the method issued by Bina Marga. The Bina Marga method is a manual method that contains design criteria that must be met to obtain a geometric road design that meets its primary purpose, namely safety. The main design criteria are the speed of the plan and the class of road users. In addition, everything related to the geometric design of the road is contained in this circular, such as the determination of corridors, visibility, the cross-section of the road, and drainage (Kriswardhana, Hasanuddin, & Palestine, 2020).

Alignment Horizontal

Road geometric design includes horizontal and vertical alignment. Horizontal alignment, commonly called arches, bends, or turns by the people, is part of the road. In one case, the researchers want to make a straight path without horizontal alignment, but alignment is needed to follow the existing topography. For example, there is a protected forest. Of course, cannot make a straight road hit the protected forest, so a horizontal alignment is made (Rusli, 2017).

The horizontal road alignment is generally a series of straight and curved road sections in a circular arc connected by a transitional arch or without a transitional arch. A multi-objective optimization method is proposed to optimize highways' horizontal alignment design, considering economy and safety (You, Yu, Huang, & Hu, 2022). The alignment of a horizontal path must be a series of straight lines (allusions) and circular curves spliced using a transition curve. The larger the circular curve/radius, the more comfortable the driver passes through the horizontal alignment. This radius depends on the speed of the plan, the superelevation of the pavement, the transverse

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roughness between the tire and the pavement, and gravity (Casal, Santamarina, & Vázquez-Méndez, 2017).

METHOD

The research location is in the Ploso District, Jombang Regency, East Java. This road aims to connect Jalan Babat with Jalan Tapen. This road is divided into two sections, and this study will discuss section 1, namely in STA 0 + 000 to STA 2 + 467. This research uses a quantifiable method. The data obtained are obtained mathematically based on existing formulas. The data used are primary data, namely situation maps, road traffic, and contours obtained from google earth. Data is one of the leading forces in compiling scientific research and modeling (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015).

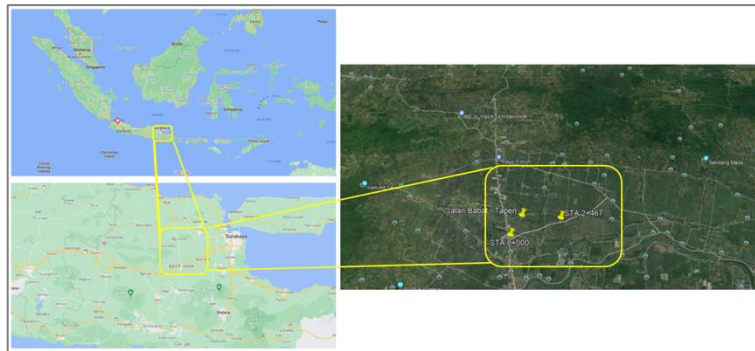


Figure 1. Research Location

These road geometric design guidelines refer to the 2021 Road Geometric Design Guidelines, which will output the results of road types and classes, road slopes, and plan speeds. This data will be used to design horizontal alignment. Systematic scientific research must identify the right problem (Rifai, Hadiwardoyo, Correia, & Pereira, 2016).

Road Trase data was created in google earth to determine the type, class, and terrain of roads based on Table 5.1 of the Highway Design Standard of Indonesia 2021. After that, the planned speed range is obtained based on data on the road's type, class, and terrain. The predefined data is then used to design horizontal alignment. First, find the coordinates of the horizontal alignment location using Google Earth, Global Mapper, and AutoCAD applications. Determine the length of the segment before the curve (D), the bend radius (R_c), the size of the bending arch (L_c), and the length of the intermediate arch (L_s). The horizontal alignment design must meet the requirements in Figure 6-14 of the Highway Design Standard of Indonesia 2021.

RESULTS AND DISCUSSION

According to the Highway Design Standard of Indonesia 2021, roads are grouped according to their designation, road network system, road status, road function, road infrastructure provider, and road user class. Jalan Tapen – Babat is a Secondary Road (Urban Road), Secondary Collector, and medium road, and the minor type of road, 2/2, is not separate (TT).

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Road Terrain Classification

Road terrain has three classifications of terrain based on topographic cross-section or what is commonly called contour. The classification of the terrain is flat, hill, and mountain. Flat terrain with notation (D) terrain slope $<10\%$, hill terrain with notation (B) terrain slope $10-25\%$, and mountain terrain with notation (G) terrain slope $>25\%$. The terrain slope value is taken on average per 50m in one kilometer. For example, Tapen Road – Tripe has a flat terrain classification because it has an average slope of 1.7% where less than ($<$) 10% .

Speed Plan

The speed of the plan is the primary design criterion. Plan velocity is obtained in table 5-1 the Bina Marga Method Standard. The correlation of equivalents between road groupings is based on a road network system. Therefore, function, status, class, road type, and plan speed range (V_D). For example, the Tapen – Babat road has a planned speed range of $20 - 40$ km/h. The plan taken has a speed of 40 km/h.

Alignment Horizontal

Jalan Babat – Tapen has a length of more than 2 kilometers road traffic planning should not only be straight and does not have horizontal alignment because it can cause monotony that can cause road users to get sleepy. For this reason, it is planned to have three horizontal arches.

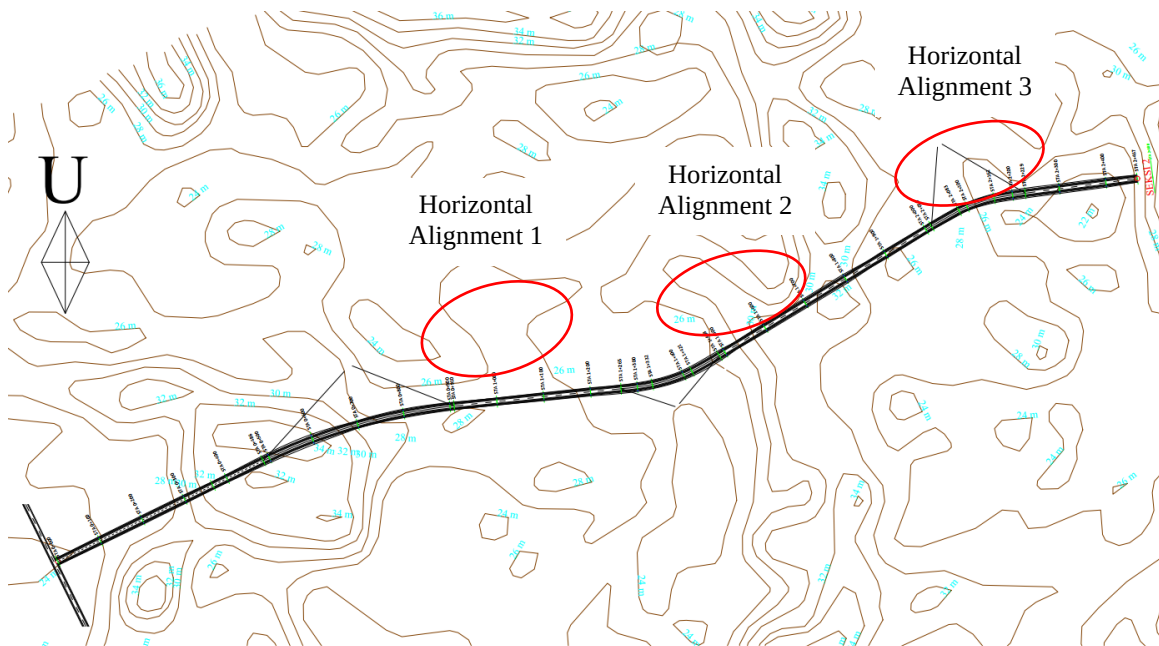


Figure 2. Alignment Horizontal Location

The coordinates of the road trace are obtained by processing data created with the help of the google earth application, global mapper, and AutoCAD. The following coordinate trace road is in three horizontal alignments Jalan Babat - Tapen.

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Table 1. Alignment Horizontal Coordinates

Point	Coordinates	
	X	Y
Start	635048.1	9177870.9
1	635676.5	9178179.2
2	636356.2	9178249.5
3	636994.9	9178639.6
Finish/Start	637337.7	9178684.3

1) Coordinate Difference (Δx and Δy)

Δx X Coordinates

$$\Delta x \text{ Initial} - 1 = 635048.17 - 635676.59 = 628.42$$

$$\Delta x 1 - 2 = 635676.59 - 636356.212 = 679.621$$

$$\Delta x 2 - 3 = 636356.212 - 636994.956 = 638.774$$

$$\Delta x 3 - \text{End/Beginning} = 636994.956 - 637337.784 = 342.828$$

Δy Coordinates Y

$$\Delta y \text{ Initial} - 1 = 9177870.916 - 9178179.28 = 308.3637$$

$$\Delta y 1 - 2 = 9178179.28 - 9178249.545 = 70.265$$

$$\Delta y 2 - 3 = 9178249.545 - 9178639.641 = 390.096$$

$$\Delta y 3 - \text{End/Beginning} = 9178639.641 - 9178684.3 = 44.658$$

2) The length of the internodes before there is an arch (D)

$$D = \sqrt{\Delta x^2 + \Delta y^2} \dots \dots \dots (1)$$

$$\text{Initial D} - 1 = 700 \text{ m} \quad \sqrt{628,42^2 + 308,36^2}$$

$$D 1 - 2 = 683,244 \text{ m} \quad \sqrt{679,621^2 + 70,265^2}$$

$$D 2 - 3 = 748,445 \text{ m} \quad \sqrt{638,774^2 + 390,096^2}$$

$$D 3 - \text{end/beginning} = 345.724 \text{ m} \sqrt{342,828^2 + 44,658^2}$$

3) Calculation of the azimuth angle (Z)

$$Z = \text{Arc tg } \frac{\Delta x}{\Delta y} \dots \dots \dots (2)$$

$$Z (\text{initial} - 1) = 63.863^\circ \text{Arc tg } \frac{628,42}{308,36}$$

$$Z (1 - 2) = 84.097^\circ \quad \text{Arc tg } \frac{679,621}{70,265}$$

$$Z (2 - 3) = 58.586^\circ \quad \text{Arc tg } \frac{638,774}{390,096}$$

$$Z (3 - \text{end/beginning}) = 82.578^\circ \text{Arc tg } \frac{342,828}{44,658}$$

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4) Calculation of the total angle (β)

$$B \text{ (initial - 1)} = |63.863^\circ - 84.097^\circ| = 20.234^\circ$$

$$B \text{ (1 - 2)} = |84.097^\circ - 58.586^\circ| = 25.510^\circ$$

$$B \text{ (2 - 3)} = |58.586^\circ - 82.578^\circ| = 23.994^\circ$$

Table 2. Coordinates, Difference Coordinates, Distance, Azimuth, and Horizontal Total Angle Alignment

Point	Coordinates		Difference Coordinates		Distance	Azimuth	β
	X	Y	ΔX	ΔY			
Start	635048,17	9177870,91					
			628,42	308,363	700	63,862	
1	635676,59	9178179,28					20,234
			679,621	70,265	683,244	84,097	
2	636356,21	9178249,54					25,51
			638,744	390,096	748,444	58,586	
3	636994,95	9178639,64					23,991
			342,827	44,658	345,724	82,578	
Finish/Start	637337,78	9178684,3					

Based on table 5-18 of the Highway Design Standard of Indonesia 2021, for a planned speed (VD) of 40 km/h, a side roughness (f) of 0.17, the maximum superelevation level (eMAKS) = 8%. Minimum finger finger (Rmin) = 50 m. Maximum relative slump (mmax) = 143. Taken R plan = 100 m and lane width (b) 3.5 m. Based on table 5-23 PDGJ 2021. For R = 100 m, Vrencana 40 km/h, length of the transitional arch (Ls) = 33, e = 6.5%.

5) Shift value in the corner (P)

$$P = \frac{Ls^2}{24 \times R} \dots \dots \dots (3)$$

$$P = \frac{Ls^2}{24 \times R} = 0,45 \text{ m} \geq 0,25 \text{ m}$$

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Since the value of P is more than equal to 0.25 m, Horizontal Alignment 1 Jalan Tapen – Tripe uses the Spiral – Circle – Spiral type.

6) Bend arch length requirements (Lc)

$$Lc \leq (6 \text{ detik} \times Vd) \dots \dots \dots (4)$$

$$Lc = \frac{\theta c}{360^\circ} \times 2\pi \times R \dots \dots \dots (5)$$

Where θc uses the total value of the angle (β)

$$\frac{\theta c}{360^\circ} \times 2\pi \times R \leq \frac{40 \times 1000}{3600 \times 6} = 34,8 \text{ m} \leq 66,6 \text{ m}$$

The value of Lc meets the requirements of the above equation.

7) Superelevation attainment length (Le)

$$Le = \text{Tangen run off (Tro)} + \text{Superelevasi run off (Ls/Sro)} \dots \dots \dots (6)$$

$$(\text{Tro}/\text{Sro}) = e \times m \text{ maks} \times b \dots \dots \dots (7)$$

$$(\text{Tro}/\text{Sro}) = 0,065 \times 143 \times 3,5 = 32,53 \text{ m}$$

$$Le = 32,53 + 32,53 = 65 \text{ m}$$

8) Transition angle (θs)

$$\theta s = \frac{90 \times Ls}{\pi \times R} \dots \dots \dots (8)$$

$$\theta s = \frac{90 \times 33}{\pi \times 100} = 9,458^\circ$$

9) The angle of the circle (θc)

$$\beta = 2\theta s + \theta c \dots \dots \dots (9)$$

Based on the results of the calculation above, the TS coordinates on the first horizontal alignment of Jalan Tapen – Babat is at STA 0 + 700, looking for ST coordinates using the formula $STA = TS + Lc + 2Le = 700 + 34.8 + 2(65) = 864.8$ or at STA 0 + 864.8. The calculation of curves two and three is the same as the calculation above. The followings are the calculation results and the location of curves two and three in the table below.

Table 3. Alignment Horizontal Calculation Result

Point	β	STA TS	R	Lc	θc	p	Ice	TS	STA ST
Start									
		700							
1	20		100	34,8	1,08	1,79	3,36	34,42	864,8
		1383,244							

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Point	β	STA TS	R	Lc	θ_c	p	Ice	TS	STA ST
2	25,5		100	44,48	6,58	1,15	3,71	39,36	1557,857
2131,688									
3	24		100	41,86	5,08	1,42	3,68	38,03	2303,685
Finish/Start									

Superelevation

The superelevation diagram shows the transverse slope in the horizontal alignment, from normal slope to full superelevation. The following is a diagram of the superelevation on the first alignment of Jalan Babat – Tapen at STA 0+700 to 0+864.8.

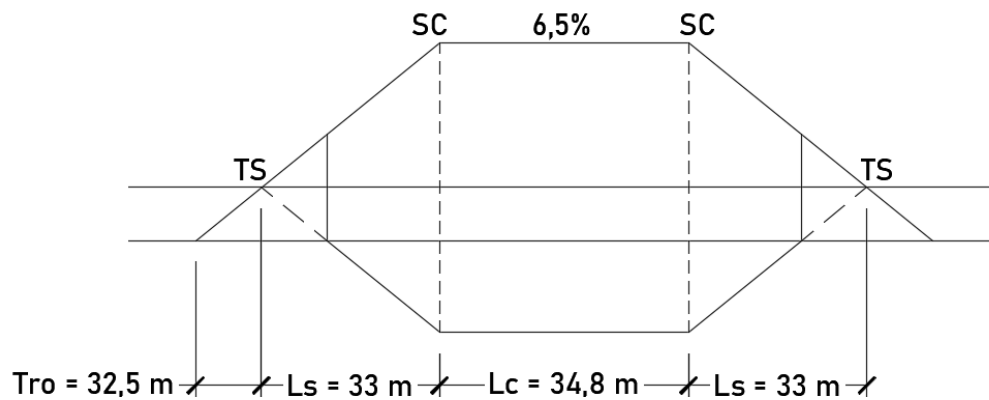


Figure 3. First Alignment Horizontal Superelevation Diagram

CONCLUSION

The design of the Horizontal Alignment of Jalan Babat – Tapen uses the Bina Marga method, namely the Highway Design Standard of Indonesia 2021. Jalan Babat – Tapen is a Secondary SJJ (Urban Road), Secondary Collector, and medium road, and the minor type of road, 2/2, is not separate (TT). The road is 3.5 m wide with a planned speed of 40 km/h and has three horizontal alignments. The first horizontal alignment used a spiral circle spiral (SCS) curved type because the p-value > 0.25 m. Using a radius of 100 m in can be rated the curved length of the bend (Lc) of 34.8 m, and the length of the transitional arch of 65 m. The main design criteria, namely the class of the road and the speed of the plan, should not be mistaken because they relate to the primary purpose of the geometric design of the road, namely safety.

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