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THE LINK ROAD DESIGN OF JALAN PLUPUH TANON AND JALAN GABUGAN SECTION 1, SRAGEN INDONESIA

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ABSTRACT

Easy community life, both in terms of economic, social, educational, and others, is the purpose of designing and constructing access roads or connecting roads. In addition, road design must consider safety aspects to achieve safe, balanced, and sustainable road performance. In this study, a manual horizontal alignment road design was carried out to link the road of Jalan Plupuh Tanon and Jalan Gabugan Sragen Section 1 from STA 0 + 000 to STA 2 + 257,221 with the planning of three bend points guided by Highway Design Standard of Indonesia 2021. Primary data in the form of coordinates and contours are taken from Google Earth and the Global Mapper. The design starts by managing primary data and calculating the elements that make up the horizontal alignment so that a road with a design speed of 30 km/h is obtained, the value of e = 8%, and a radius of 200 m. Three horizontal alignment points use a Spiral-Circle-Spiral (SCS) arch with an intermediate curve (Ls) value of 38 m and a circular arch (Lc) of 44.229 m, respectively.

INTRODUCTION

Roads are built and maintained to provide services, such as the capacity to move people and products within a predetermined period, with the probability of goods being damaged and people injured or losing their lives relatively low. Therefore, the main goal of the road is safe to achieve safe, balanced, and sustainable road performance. This is reflected in geometric road planning, which includes symmetrical placement of physical elements of roads, cost (efficiency) analysis, reduction of adverse environmental impacts, traffic volume, road accessibility, and others. In addition to ensuring a higher level of road safety, other objectives of the road also include maximizing economic effectiveness in the construction of road infrastructure and reasonable goal accessibility time to maintain sustainable social, environmental, and economic growth (Adey, Burkhalter, & & Martani, 2019); (Mitrović Simić, Stević, Bogdanović, Subotić, & & Mardani, 2020); (Sedivy, et al., 2021).

As a result of the ability of roads to promote economic growth and improve human well-being, the road network is increasing at an unprecedented pace in the world. It is linked to the ability of each region to develop and compete globally because it facilitates the transportation of people and goods, communicates information, and provides access to essential services, all of which are prerequisites for the contemporary economy. The World Economic Forum analyzed the improvement of living standards in 140 countries each year, and the results showed that geographic regions with more vital connectivity experienced greater prosperity. In terms of public welfare, road infrastructure is critical (Carter, Killion, Easter, Brandt, & & Ford, 2020); (Ruiz & Guevara, 2020); (Mejía, Sánchez, Castañeda, & Pellicer, 2020).

Indonesia has set a national goal to improve infrastructure initiatives essential for better logistics and transportation. In addition, the government prioritizes improving institutional connectivity with a specific focus on specific areas. By improving institutional connectedness, social, economic, cultural, and educational efforts will be strengthened by improving institutional connectedness and access and mobility for individuals across the archipelago (Leung, 2017).

Especially in the Sragen Regency of Central Java, road planning is very important to achieve Indonesia's national goals in the country's transportation network. One example of a cross-regional connectivity application is the road connecting Jalan Plupuh Tanon and Jalan Gabugan Sragen. Based on the ground's contours, this road's location is the most efficient and shortest distance compared to alternative routes. In addition, using these highways helps the region and its surroundings realize their full potential in the small and medium enterprises and tourism sectors.

Road planning was carried out manually in this study using SE PDGJ 2021 (Highway Design Standard of Indonesia 2021) as guidelines and standards. Therefore, this planning applies only to Section 1 of STA 0+000 to STA 2+257.221, where the intended geometric alignment of the road is horizontal.

The systematic scientific research process must begin with identifying the exact problem. Therefore, based on the background information and description that has been given above, the author is interested in manually designing a horizontal alignment road in the city with a second local road classification, namely the type of 2-lane 2-way undivided road (2/2 TT) with a planned speed of 30 km / h (Rifai, Hadiwardoyo, Correia, & Pereira, 2016).

LITERATURE REVIEW

Road Geometric Planning

The transport network is a fundamental component of the civil infrastructure and a key element of sustainable development and is essential for the effective and reliable operation of the transport system. Moreover, roads are part of the infrastructure that helps a region develop its potential while facilitating the movement of people and the delivery of commodities. Therefore, when the local economy undergoes a relatively large expansion, the availability of roads is seen as urgent (Mahanpoor, Monajjem, & Balali, 2021); (Howe, 2019); (Nolte, Kister, & Maurer, 2018).

To meet the road infrastructure, geometric road planning is needed, which is part of road planning that focuses on physical shape planning so that it can fulfill the essential function of the road, namely providing optimal service to traffic flow and maximizing the ratio of the level of use of implementation costs to provide a sense of security and comfort for road users. In addition, geometric road planning includes several elements adapted to the completeness and existing primary data from field survey results and has been analyzed and referred to applicable provisions (Jima & Sipos, 2022); (Malaghan, Pawar, & He, 2021).

Geometric planning of roads is used as a preliminary step in constructing connecting roads or access roads. The access road is a road that connects one road with another that already exists to achieve goals both in terms of economic, social, educational, and others that facilitate people's lives. Access roads provide access to infrastructure such as markets, schools, and hospitals, while the high transportation costs associated with poor transport infrastructure tend to hinder development. Research on access road planning to the Bailey Mountain Bridge Span states that the results of geometric planning use a 2/2 UD road type, a lane width of 2.75 m, a plan speed of 30 km / h, a total road length of 569.06 m consisting of 5 intersection point (Wenz, Weddige, M., & Steckel, 2020); (Hasan, Firdaus, Sundara, & Astor, 2020).

Alignment Horizontal

Horizontal alignment consists of straight lines connected by curved lines. The curved line may consist of a circular arch plus an intermediate arch. The horizontal alignment includes a straight section of the road and a circular arch connecting the change of direction. The design of the linemen depends mainly on the design speed chosen for the road. The most critical part of the horizontal alignment is in the bend, where a centrifugal force pushes the vehicle out of the corner area. Therefore, for the safety of road users, the planning of curve sections needs to consider things such as maximum transverse slope, switching curve, visibility, side-free area, and widening of traffic lanes in the bend area (García, Camacho-Torregrosa, & Baez, 2020); (Garber & Hoel, 2018); (You, Yu, Huang, & Hu, 2022).

The horizontal alignment is divided into three elements that have a relationship between the steering wheel of the vehicle and the longitudinal axis of the body, such as 0° (straight line), constant (circular arch), or changeable (intermediate arch). For zero curvature (0°), the line of the running track has an indefinite radius, so the line is straight. The circular arch and relief arch are usually combined with a straight line, for example, connecting the circular arch to another circle's circular arch or the intermediate arch. The circle curve is mainly used to turn and change the vehicle's direction. For constant curvature, the line has a circular curvature because the radius of the running track line is also constant. For changeable curvature, the radius of the running track line also varies, shifting from infinity to a constant value, causing the line to change from a straight line to a circular arc. As long as the use is appropriate for each element and is well designed, then it can meet the driving requirements, besides there are no consistent restrictions to limit the number and frequency of use of such elements when building public roads (Pei, He, Ran, Kang, & Song, 2020).

The road is a three-dimensional tape; Its projection line on the horizontal plane is referred to as the horizontal alignment of the road, and the shape of its midline space is referred to as the route. The development of horizontal alignment theory to support effective and safe road planning is growing, one of which is using trajectory speed. This method is most suitable for designing horizontal alignment of slow-moving highways through bumpy terrain, especially two-lane mountain routes. This method can be incorporated into the current design process by adding additional design steps, given that street designers still work in the traditional way in different countries. Current route optimization software can also be equipped simultaneously with decision models. Based on research, horizontal alignment can influence the prediction of the trajectory of a typical directional control pattern in the pavement width that motorists can use (He & Pei, 2017); (Xu, Lin, & Shao, 2017).

Manual Road Design

Manual road design is a design that is carried out and taken into account by referring to applicable regulations. In Indonesia, MKJI 1997 (Indonesian Highway Capacity Manual, 1997) is used as a manual for the analysis, planning, design, and operation of traffic facilities such as signaled intersections, interchanges, and interlaced and roundabout sections, as well as roads (urban roads, intercity roads, and toll roads). This guide is mainly designed so that users can estimate the traffic behavior of a facility in specific traffic conditions, geometry, and environmental conditions (Isradi & Primary, 2020).

In addition to MKJI 1997 (Indonesian Highway Capacity Manual, 1997), SE PDGJ 2021 (Highway Design Standard of Indonesia 2021) is a more specific guideline in geometric road planning. This guideline is intended as a technical reference for geometric road designers to obtain the minimum and maximum limits of their design parameters by considering the ideal design requirements, field survey results, and terrain conditions.

In addition, various countries have their manuals for designing roads, such as the USA using AASHTO (American Association of State Highway and Transportation Officials), Japan using JRA (Japan Road Association), Indians using IRC (Indian Road Congress), and others. Each guide differs depending on the conditions in each country that are made to produce products that are accurate in design, meet needs and technical rules, and can be applied in physical execution in the field.

METHOD

Road Design Data

Data is one of the leading forces in compiling scientific research and modeling. After the preparation period before the study is carried out, data collection is then carried out. The data are obtained according to the research plan for the appropriate and appropriate data. In obtaining and managing data, this study uses a literature method which is a method for identifying and processing written materials used in library data collection activities (Rifai, A. I., Hadiwardoyo, S. P., Correia, A. G., Pereira, P., & Cortez, P., 2015); (Rifai, Surgiarti, Isradi, & Mufhidin, 2021); (Rifai, Wibowo, Isradi, & Mufhidin, 2020).

The location of the road design is in Sragen Regency, Central Java, especially the road that aims to connect Jalan Plupuh Tanon with Jalan Gabugan Sragen, shown in ***Figure***. The road to be built consists of 2 sections, while in this section, the planning will be discussed in section 1 from

STA 0 + 000 to STA. STA 2+257.221. The data is taken from Google Earth and Global Mapper, the primary data used for road design in this region.

Figure1 1. Road Planning Location

This study uses road class regulations based on road functions and classifications referring to Highway Design Standard of Indonesia 2021, page 30, Table 4-1, page 42, Table 5-1, and page 49, Table 5-3. The results of the calculation of geometric elements will subsequently be presented in the form of data tables and superelevation drawings.

RESULTS AND DISCUSSION

Horizontal Alignment Design

The road designation is designed as a public road with the status of a city road with a function as a secondary local road. The road is classified as Class III (Class 3) with type 2/2-TT and a lane width of 3.5 m. The plan speed (Vd) is 30 km/h, where the road terrain is flat with a slope of < 10% for a geometric length of 2,257 km. Here are the road route coordinates listed in Table 1 below.

Table 1. Coordinates of The Road Route

Point	X	Y
Start	488,154.1650	9,181,782.228
1	488,797.2658	9,181,819.269
2	489,433.1580	9,181,714.223
3	490,077.4183	9,181,760.859
End/Start	490,398.9486	9,181,720.333

Based on the coordinates of the road route data above, the theta angle (θ) is as follows:

a. Coordinate Difference

Δx start-1= coordinate point x 1 – coordinate point x start
= 488,797.1658 - 488,154.1650
= 643,092 m

Δx start-1= y-coordinate point 1 – y coordinate point start
= 9,181,819,269 - 9,181,782,228
= 37,041 m

Δx 1-2= coordinate point x 2 – coordinate point x 1
= 489,433,1580 - 488,797,1658
= 635,901 m

Δy 1-2= y2 coordinate point – y coordinate point 1
= 9,181,714,223 - 9,181,819,269
= -105,047 m

b. Internode Length Before Arch

The results of the calculation of coordinate differences are processed into calculations of the distance between points so that the path length is known as follows:

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

Information:

Δx^2 = selisih koordinat x

Δy^2 = selisih koordinat y

$$\mathrm{Dstart} - 1 = \sqrt{643.092^2 + 37.041^2} = 644{,}158 \text{ m}$$

$$\mathrm{D1} - 2 = \sqrt{635.091^2 + (-105.047)^2} = 644{,}519 \text{ m}$$

c. Azimuth Angle (Z)

The results of the calculation of coordinate differences are also processed into azimuth angle calculations as follows:

$$\mathrm{Z} = \arctan \frac{\Delta x}{\Delta y} \quad (2)$$

Information:

Δx^2 = selisih koordinat x

Δy^2 = selisih koordinat y

$$\mathrm{Zstart} - 1 = \arctan \frac{643.092}{37.041} = 86.704°$$

$$\mathrm{Z1} - 2 = \arctan \frac{-(-105.047)}{635.091} + 90 = 99.380°$$

d. Theta Corner (θ)

$\theta 1 = (Z1 - 2) - (Zstart - 1) = 99.380° - 86.704° = 12.677$

The complete calculation results for all the above points are shown in Table 2 below.

Table 2. Coordinates Calculation Result

Point	X	Y	ΔX	ΔY	Length	Azimuth	θ	STA
Start	488,154.16	9,181,782.22						
			643.092	37.041	644.158	86.704		644.158
1	488,797.26	9,181,819.26					**12.677**	
			635.901	-105.047	644.519	99.380		1288.677
2	489,433.15	9,181,714.22					**13.520**	
			644.260	46.636	645.946	85.860		1934.623
3	490,077.41	9,181,760.85					**11.324**	
			321.530	-40.526	324.074	97.184		2258.697
End/Start	490,398.94	9,181,720.33						

Horizontal Alignment Calculation

Based on table 5-18, page 96 on SE PDGJ 2021 (Highway Design Standard of Indonesia 2021), Rmin with Vd = 30 km/h and e = 8% is 30 m, so the value of R = 200 m, and based on table 5-21 page 101, the value of m max = 133.

Ls (Sro) ≥ e × B × m max .... (3)

Information:

e= superelevation rate, %

B= lane width, m

m = relative slope equivalent

Ls (Sro) ≥ 37.24 m ≈ 38 m

Run out (Tro) = e x b x m max .... (4)

Information:

e= superelevation rate, %

B= lane width, m

m = relative slope equivalent

Run out (Tro) = 0.08 x 3.5 x 133 = 37.24 m ≈ 38 m

Le = Run out + ls = 38+ 38 = 76 m

$p = \frac{Ls^2}{24R}$..(5)

Information:

Ls= length of intermediate arch, m

R= radius, m

$$\mathrm{p} = \frac{38^2}{24 \times 200} = 0.301\ \mathrm{m} \geq 0.25\ \mathrm{m}\ (\mathbf{spiral - circle - spiral})$$

Lc for Vd = 30 km/h for 6 seconds = 50 m

$Lc = \frac{\theta c}{360°} \times 2\pi \times R$ .... (6)

Information:

Lc= curved length of the circle, m

Θc = angle of the circle, ∘

R= radius, m

$$\mathrm{Lc} = \frac{12.677°}{360°} \times 2\pi \times 200 = 44.229\ \mathrm{m} < 50\ \mathrm{m}\ (\mathrm{R} = 200\ \mathrm{m\ can\ be\ used})$$

R value = 200 m, the calculation of the planning of the Spiral-Circle-Spiral (SCS) arch is described as follows:

$\theta s = \frac{90 \times Ls}{\pi \times R}$ ....(7)

Information:

Θs = angle of switching arch, ∘

Ls= length of the intermediate arch, m

R = radius, m

$$\theta\mathrm{s} = \frac{90 \times 38}{\pi \times 200} = 5.446°$$

$\beta = 2\theta s + \theta c$..(8)

Information:

β = total angle, ∘

Θc = angle of the circle, ∘

Θs = angle of switching arch, ∘

$\theta\mathrm{c} = \beta - 2\theta s = 12.677 - (2 \times 5.446°) = 1.785°$

$p = \frac{Ls^2}{6R} - R(1 - cos\theta c)$...(9)

Information:

p= tangent shift towards spiral, m

Ls= length of transition arch, m

R = radius, m

Θc = angle of the circle, ∘

$$\mathrm{p} = \frac{38^2}{6 \times 200} - 200(1 - \cos 1.785°) = 1.106\ \mathrm{m}$$

$Es = \frac{R+p}{Cos^1/_2\beta} - R$..(10)

Information:

β = total angle, ◦

R = radius, m

p= tangent shift towards spiral, m

$$\text{Es} = \frac{200 + 1.106}{\text{Cos}(6.339)} - 200 = 2.320 \text{ m}$$

$k = Ls - \frac{Ls^3}{40R^2} - (R \times sin\theta s)$...(11)

Information:

k= straight distance between the starting point of curvature and the displacement point of the circular arc, m

Ls= length of intermediate arch, m

R = radius, m

Θs = angle of switching arch, ◦

$$\text{k} = 38 - \frac{38^3}{40 \times 200^2} - (200 \times \sin 5.446°) = 18.984 \text{ m}$$

$TS = (R + p)tan\frac{\beta}{2} + k$..(12)

Information:

TS= tangent point to spiral, m

R = radius, m

p= tangent shift towards spiral, m

k= straight distance between the starting point of curvature and the displacement point of the circular arc, m

$$\text{TS} = (200 + 1.106)\tan\frac{12.677}{2} + 18.894 = 41.233 \text{ m}$$

$Xs = Ls\left(1 - \frac{Ls^2}{40 \times R^2}\right)$..(13)

Information:

Xs= abscissa of the point SC on the tangent, the distance of the point TS to SC (transition straight arc distance), m

Ls= length of the spiral arch, m

R = radius, m

$$\text{Xs} = 38\left(1 - \frac{38^2}{40 \times 200^2}\right) = 37.966 \text{ m}$$

$Ys = \frac{Ls^2}{6R}$.. (14)

Information:

Ys= coordinates of the point SC on the perpendicular line of the tangent, the perpendicular distance of the point SC on the arc, m
Ls= length of the intermediate arch, m
R = radius, m

$$\text{Ys} = \frac{38^2}{6 \times 200} = 1.203 \text{ m}$$

The TS point is at STA 0+644.158, then the ST point is at STA = TS + Lc + 2Le = 644.158 + 44.229 + 2(76) = 840.387 or STA 0+840.387.

The above calculations are implemented for the other 2 points shown in **Table 3** below.

Table 3. Horizontal Alignment Calculation Result

Point	θ	STA TS	R	Lc	θc	p	Ice	TS	STA ST
Start									
		644.158							
1	**12.677**		200	44.229	1.785	1.106	2.320	41.233	840.387
		1288.677							
2	**13.520**		200	47.169	2.628	0.993	2.400	42.718	1487.846
		1934.623							
3	**11.324**		200	39.508	0.432	1.197	2.183	38.841	2126.131
		2258.697							
End/Start									

Superelevation

Superelevation is slope transverse road at one Turn that Functions to Offset style Centrifugal that works the moment the vehicle walks cornering, Stated deep unit % (Highway Design Standard of Indonesia 2021). By the account of the above Diagram, superelevation Is shown in Figure 2.

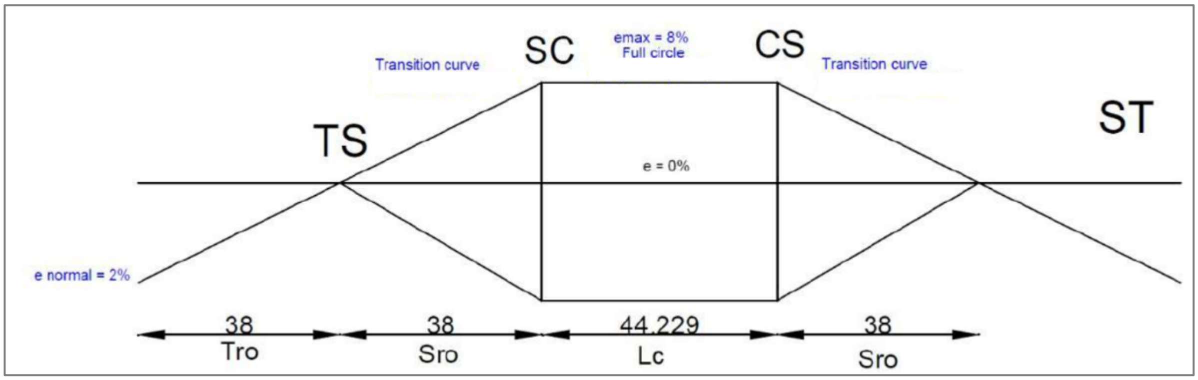

Figure2 2. Superelevation Diagram

CONCLUSION

The data processing results and horizontal alignment design connecting the Plupuh Tanon – Gabugan Sragen Section 1 road section from STA 0 + 000 to STA 2 + 257,221 can be drawn from several conclusions. The road is designed with the status of a city road and serves as a secondary local road, has a design speed (Vd) of 30 km/h, uses a spiral-circle-spiral (SCS) arch, and has an e value of 8%. The transitional curve length value (Ls) is 38 m, and the circular arch length value (Lc) is 44.229 m, with a radius (R) of 200 m for all three horizontal curve points that are planned and have met the existing requirements.

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