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The redesign of provincial road geometric used AutoCAD®2D: A case Jalan Majalengka-Rajagaluh, Indonesia

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ABSTRACT

Jalan Majalengka-Rajagaluh is a road located in several sub-districts that is a link to the city and one of the connecting roads to Cirebon City. This design planning began in Cigasong sub-district and continued to Rajagaluh sub-district with a length of 5.3 kilometers on the Majalengka-Rajagaluh road. The results of the geometric design are visualized in the form of drawings using AutoCAD 2D. The design speed (Vd) is set at 60 km/h with a horizontal curve radius of 358 m, a maximum slope of 4%, and an elevation (e max) of 8%. Based on this design criterion, a spiral curve with a circular arch length (Lc) of 74,996 m was obtained. Furthermore, the results of the calculation of the vertical alignment of the length (L) of one type of convex curve in the PPV are also calculated.

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INTRODUCTION

Roads are a beneficial means of transportation to connect various locations, such as industrial centers, agricultural areas, and settlements, as well as distributing goods and services to support economic activities (Purnama et al., 2022). Infrastructure development can be in the form of roads, toll roads, bridges, etc. (Capacci et al., 2022; Gautam, 2020; Koul et al., 2021). Road infrastructure development can be in the form of the construction of supporting infrastructure from a road. Various countries develop road infrastructure to meet the needs of a fulfilled road. Increasing the number of roads proves the critical role of road infrastructure in the development of each country (Zulfa et al., 2022).

The rapid economic development in Indonesia has caused traffic congestion to increase. With a population exceeding 230 million, the country's economic growth has driven increased demand for transportation and vehicle ownership (Ulchurriyyah et al., 2023). Therefore, road infrastructure construction is intensively carried out in Indonesia to anticipate the explosion of traffic flow in an area (Pribadi et al., 2021; Riefky et al., 2021; Rifai et al., 2021). Highways in Indonesia are divided into National Roads, Provincial Roads, Regency Roads, City Roads, and Village Roads following the Law of the Republic of Indonesia No. 38 of 2004 and Government Regulation No. 34 of 2006 concerning the status of roads (Rizqi et al., 2022). Roads can also affect all economic activities in Indonesia. It is expected that Indonesia's national economy will experience significant growth after ten years of making major investments in public infrastructure projects, the focus of which is the construction of new roads, railways, ports, airports, power plants, energy distribution, clean water supply and sanitation, and the construction of schools and hospitals (Nugroho et al., 2023). Thus, road geometric planning in Indonesia dramatically affects the productivity of road infrastructure development.

Majalengka City is one of the various cities that are building road infrastructure. One of the developments in the existing infrastructure in Majalengka is the construction of the Cipali toll road. Due to the identified economic benefits, the construction of toll roads in Indonesia under President Joko Widodo was carried out massively (Rahayu et al., 2022). Infrastructure development is undoubtedly caused by various factors, including the construction of the West Java International Airport (BIJB) in Kertajati, Majalengka. Road infrastructure must be developed to support activities at the airport.

Jalan Majalengka-Rajaglauh is a link to the direction of Cirebon City. Road geometric planning is a planning approach that focuses on its physical design to ensure the road is following its function. Generally, road geometric planning is done manually using drawing tools and mathematical techniques (Salsabila et al.,

2023). Geometric planning of roads can be done using AutoCAD®2D software. The use of AutoCAD® technology in highway surveying and design has resulted in significant changes in the traditional way of doing highway design (Adiputra et al., 2022). Therefore, by being practical and time-efficient, geometric replanning on the Majalengka-Rajagaluh road can use AutoCAD®2D software.

This paper aims to plan the geometry of the Majalengka-Rajagaluh road in the western region of Majalengka. This is scheduled to increase land transportation facilities and connect the Panyingkiran sub-district to urban areas. The location was chosen to renew the road in the area. Based on the above problems, a redesign was carried out on the road precisely on Jalan Majalengka-Rajagaluh along 4 KM. By creating horizontal and vertical alignments along 4 KM with manual calculations and using AutoCAD®2D software. This research is expected to be an efficient and effective highway geometric design solution.

METHOD

Data is one of the main strengths in preparing scientific research and modeling. It can also be used as a reference to determine the area's situation. The data used in this geometric design planning is obtained from Google Earth, which is processed into Global Mapper and AutoCad®2D. This design planning starts at Jalan Majalengka-Rajagaluh. This net has a length of 5.3 km.

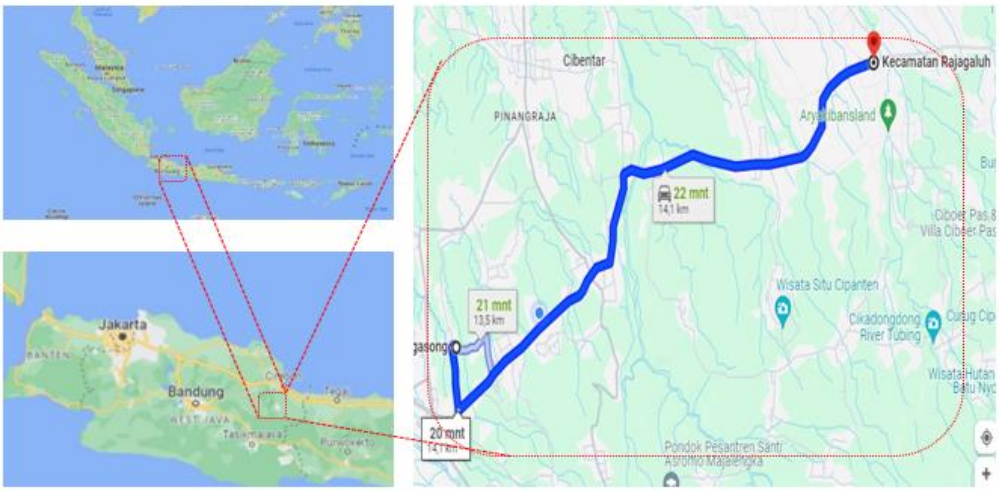

Figure 1. Research Location

Road geometric design planning requires supporting data to get a safe and efficient job. The method used for the geometric planning criteria on this road is also a combination method. The quantitative research method uses mathematical sample data to produce the results of geometric road planning following the set standards (Adiputra et al., 2022). The data needed in this study are primary data and secondary data

Primary data itself is usually obtained by effort for field observation results. A designation observation method is a technique to collect data by observing and recording the state of the object being targeted (Oktobrianto et al., 2023). Meanwhile, secondary data is obtained through the relevant sources without conducting research or observation. Secondary data in this study is soil contour data from Google Earth. Furthermore, the data from Google Earth will be processed using a global mapper. After that, the mapper's global result data will be reprocessed in Autocad to bring up sufficient contours and horizontal and vertical data alignments. The geometric design results will be visualized as drawings using AutoCAD®2D.

RESULTS AND DISCUSSION

Design Criteria

The Majalengka-Rajagaluh road, which runs from the Kadipaten district to the Panyingkiran district in Majalengka Regency, is included in the primary local road type III class. This study's results are based on the Road Geometric Design Guidelines (Directorate General of Highways, 2021).

Table 1. Criteria Design

Road Name	Road Type	Road Function	Classification	Plan Speed	Maximum Elevation (E maks)	Cross Error (f max)	Width of Road
Jalan Majalengka-Rajagaluh	2/2 OUT	Primary Local	Hill	60 KM/hours	8%	0,17	3,50 m x 2

Horizontal Alignment

The following is data obtained from the Majalengka-Rajagaluh road section, which is used to calculate the horizontal alignment (spiral-circular-spiral). The Majalengka-Rajagaluh road is classified as a significant local road with class III, and this terrain is flat, so the design speed range (VD) has been obtained between 20 and 60 km/h, as shown in Table 5.1 in the Road Geometric Design Guide (Director General of Highways, 2021).

The first step is to calculate the minimum radius (R min) using the maximum superelevation value (e max) of 8%, the design speed (VD) of 60 km/h, and the cross-sectional error value (f max), which is calculated using equation (2).

$$R\min = \frac{V\text{^}2}{127(e\ max + f\ max)} \quad (1)$$

$$R\min = \frac{60\text{^}2}{127\ (0{,}08 + 0{,}153)} = 112\ m$$

To calculate the f max in the equation above, i.e. using the equation below, the design speed (VD) value is < 80 km/h.

$$f\ max = -0{,}00065v + 0{,}192 \quad (2)$$

$$f\ max = -0{,}00065 \times 60 + 0{,}192 = 0{,}153$$

After determining the value of the r min in Equation (1), the next step is to calculate the length of the transition curve (Ls). The values required in this calculation include the design speed (VD) value = 60 km/h and travel time, equal to 3.

$$Ls = \frac{VD}{3{,}6} \times T \quad (3)$$

$$Ls = \frac{60}{3{,}6} \times 3 = 50\ meter$$

From the above calculations, the minimum value of the length of the transition arch is 50 m. The radius is R=358. Which has a maximum superelevation value of 8% and a width of 3.50 lanes. After determining the Ls value, which is 50 m, we look at Table 5-32 (p.114) of the Road Geometric Planning Guidelines (Directorate General of Highways, 2021) to have an e value of 5.6%, or 0.056.

The next step is to calculate the curve, or horizontal spiral curve (θs), using the known values of the minimum transition curve length (Ls) and the minimum curve radius (Rc).

$$\theta s = \frac{90.Ls}{\pi\ .\ Rc} \quad (4)$$

$$\theta s = \frac{90.50}{\pi\ .\ 358} = 4{,}001°$$

The result of the above calculation is that the value of the horizontal spiral curve (θs) is 4.0010. After determining the value of the horizontal spiral curve, the value of the horizontal circle curve (c) is calculated. Before doing the calculations, we must know the value of the beta coefficient (β) using the known horizontal curve value (s).

$$\theta c = \beta - 2\theta s \quad (5)$$

$$\theta c = 20° - 2(4{,}001°) = 11{,}998°$$

Once it is known that the value of the horizontal circle curve (θc) is 11.9980, furthermore, the value of the design curve (Lc) is calculated using the value of c known in Equation (5).

$$Lc = \frac{\theta c}{360} \times 2\pi Rc \quad (6)$$

$$Lc = \frac{11{,}998}{360} \times 2\pi 358 = 74{,}996\ m$$

Check Lc>20m, 74, 996 m > 20 m .....

(OK)

In the above calculations, the Lc value is 74.996 and is proven to exceed 20 m. The total length (L) is obtained from the sum of the design curve values (Lc) by 2 × the transition curve values (Ls), both known in equations (3) and (6).

$$L = Lc + (2 \times Ls) \quad (7)$$

$$L = 74{,}996 + (2 \times 50) = 174{,}996\ m$$

From these calculations, it can be observed that the total length of the design curve (L) is 174,996 m. The next step is to determine the value of the tangential spiral (P) using the length of the transition curve (Ls), the design radius (Rc), and the horizontal spiral curve (θs).

$$P = \frac{Ls^2}{6RC} - Rc\,(1 - cos\theta s) \quad (8)$$

$$P = \frac{50^2}{6 \times 358} - 358\,(1 - cos4{,}001) = 0{,}291m$$

The spiral tangential value (p) obtained from the calculation above is 0.291 m. Then, the spiral tangential junction (K) is determined using the length of the transition curve (Ls), the design radius (Rc), and the horizontal spiral curve (θs).

$$K = Ls - \frac{Ls^3}{40 \times Rc^2} - Rc \times sin\theta s \quad (9)$$

$$K = Ls - \frac{Ls^3}{40 \times 358\text{^}2} - 358 \times sin4{,}001 = 24{,}954$$

340,67 < 361,87 ..... (OK)

From the calculation above, the abscissa value at the spiral tangent (K) was obtained at 24.954. Next, the next step is to find the value of the distance P1 to the circle (Es) using the design radius value, spiral tangent (P), and beta coefficient, all of which are already known above.

$$Es = (Rc + P)\sec\frac{1}{2}\beta - Rc \quad (10)$$

$$Es = (358 + 0{,}291)\sec\frac{1}{2}20 - 358 = 6{,}808\,m$$

Therefore, the distance of the angle (P1) to the circle is 6,808 m. Then, the value of the spiral tangent meeting point (TS) or spiral tangent meeting point (ST) has been obtained. The values used are the radius of the plane (Rc), the spiral tangent (P), the beta coefficient (β), and the abscissa p value on the spiral tangent (K).

$$TS = (Rc + P)tg\frac{1}{2}\beta + k \quad (11)$$

$$TS = (358 + 0{,}291)tg\frac{1}{2} \times 20 + 25 = 87{,}535\,m$$

It can be seen in Equation (11) that the value of the meeting point of the spiral tangent line (TS) or the meeting point of the spiral to the tangent line (ST) is 87.535 m. After determining the above values, the relative slope has been calculated by determining the width of the road (L), the length of the spiral curve (Ls), and the value of the coefficient (e).

$$= L\frac{(e + en) \times B}{Ls} \quad (12)$$

$$= 3{,}5\frac{(0{,}2 + 0{,}59)}{50} = 0{,}0553$$

After counting all the components of the horizontal alignment, the results are shown in the following figure:

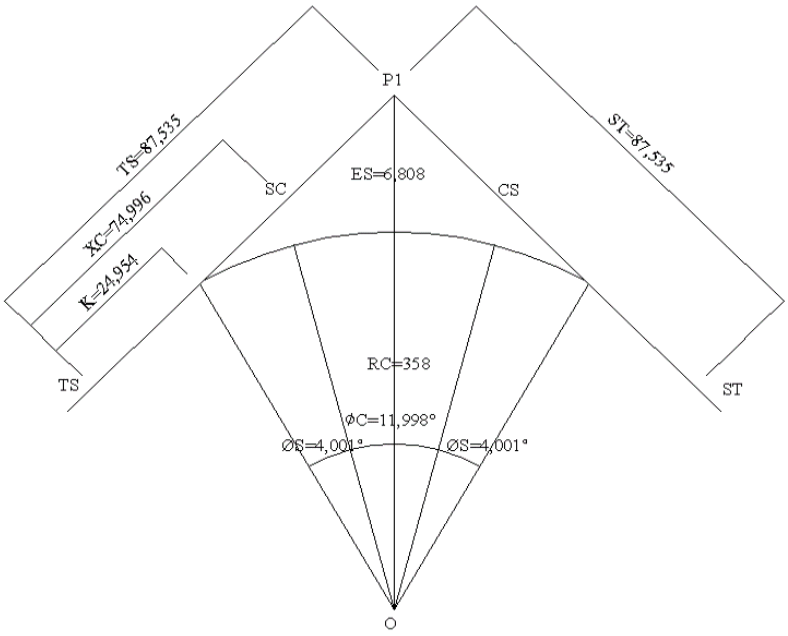

Figure 2. Horizontal Alignment

Superelevation Diagram

Based on the known horizontal alignment curve diagram, the superelevation diagram is shown in the figure below.

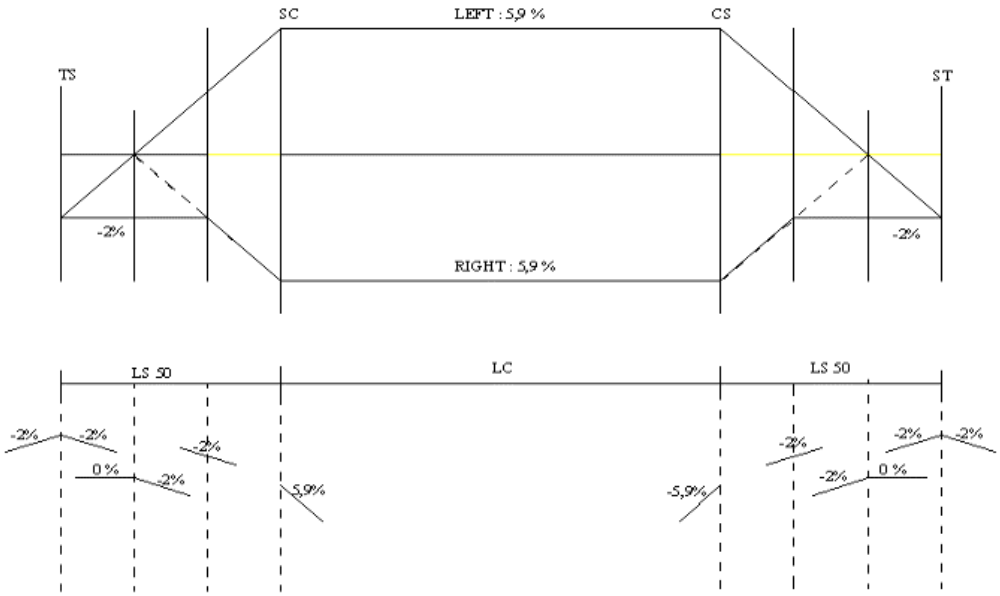

Figure 1. Superelevation Diagram

Vertical Alignment

The vertical alignment in this section is visualized using AutoCAD® 2D along Jalan Majalengka-Rajagaluh from Sta 0+000 to Sta 5+400. A picture of the vertical alignment is shown in the picture below.

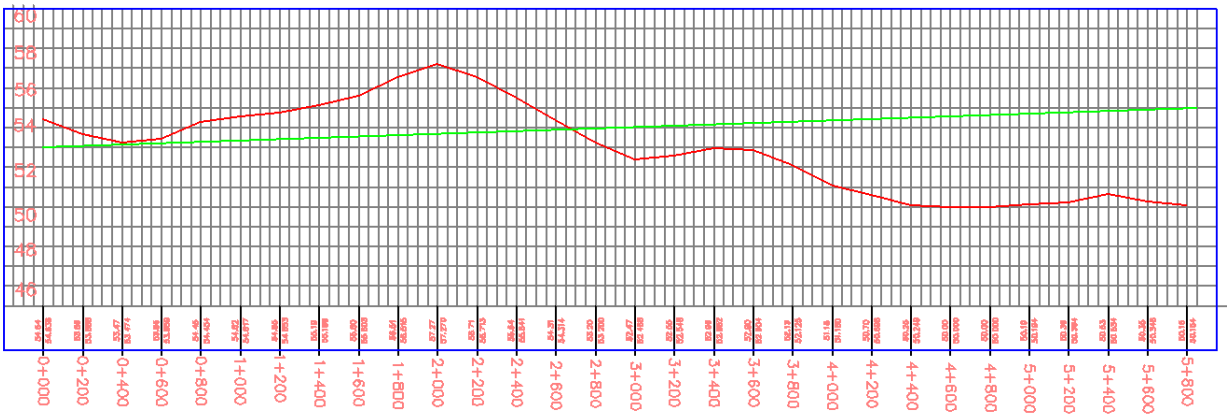

Figure 2. Vertical Alignment

Based on the above adjustment, the PPV (Vertical Section of the Intersection) point has been determined at the station. 1+800; The height of the point is 58.00 m. After that, the starting point is set at Sta. 1800, with an altitude of 58.00 m, the end point at Sta. 2+000, and the altitude is 53.00 m. Once the above information is generated, the slope values (g1 and g2), the slope algebraic difference (A), and the length of the vertical curve (L) can be calculated using the following equation:

$$g1 = \frac{elv.PPV - elv.beginning}{Sta.PPV - Sta.beginning} \times 100\% \quad (13)$$

$$g1 = \frac{58{,}00 - 58{,}00}{1.800 - 1.800} \times 100\% = 0\%$$

$$g1 = \frac{elv.end - elv.PPV}{Sta.end - Sta.PVV} \times 100\% \quad (14)$$
$$g1 = \frac{53{,}00 - 58{,}00}{2.000 - 1.800} \times 100\% = 0{,}40\%$$

$$A = g1 - g2 = 0\%\text{-}0{,}4\%\text{=-}0{,}4\% \text{ (concave arch)} \quad (15)$$

Based on the design speed (VD) value, which is 60 km/h, the K value refers to Figure 5-44 (p.164), which is used to calculate the length of the vertical curve (L) in the calculation below.

$$L = K.A \quad (16)$$
$$L = 16 \times (-0{,}40\%) = 64\ m$$

From the value of the vertical curve length (L), the value of the vertical shift from the PPV point to the turn point of the transverse cut can be determined using the calculation below.

$$Ev = \frac{AL}{800} \quad (17)$$
$$Ev = \frac{0{,}40 \times 64}{800} = 0{,}032\ m$$
$$X = \frac{1}{4} \times L = \frac{1}{4} \times 64 = 16\ m$$
$$Y = \frac{A.X\text{^}2}{200.L} = \frac{0{,}40.16\text{^}2}{200.64} = 0{,}008\ m$$

After searching for the results of the calculation above, some data was obtained. The slope of the road (A) is −-0.4% (concave curve). In addition to this data, the value of the length of the vertical curve (A) is 64 meters. The vertical shift from the PPV point to the turning point (elv) is 0.032 m. The X value is obtained from the above data, which is 16 m, while the Y value is 0.008 m.

CONCLUSION

The Majalengka-Rajagaluh Highway was designed using AutoCAD® 2D method and Road Geometric Guidelines. The design speed was set at 60 km/h, with a horizontal curve radius of 358 m, a maximum gradient of 4 n, and a maximum elevation of 8%. A spiral arch with a circular arch length of 74.996 m was obtained. The vertical alignment of a concave curve was calculated to be 64 m. Future studies could explore the impact of design speeds and geometric parameters on road safety and efficiency in different terrains. The integration of 3D modeling tools like AutoCAD® Civil 3D or Building Information Modeling could improve accuracy in road design and visualize potential environmental impacts. Long-term performance and maintenance requirements of roads designed using these geometric principles in real-world conditions are also of interest.

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