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ROAD GEOMETRIC REDESIGN USED AUTOCAD®2D: A CASE JALAN SILIWANGI MAJALENGKA, INDONESIA

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ABSTRACT

Jalan Siliwangi is a road located in Panyingkiran that is a link to the city. This design planning starts in the Kadipaten sub-district and extends to the Panyingkiran sub-district is called jl. Siliwangi is 5.3 kilometers long. In addition, the design standard criteria in this study refer to the road geometric guidelines issued by the Ministry of Public Works and Public Housing Circular Letter of 2020 of the Director General of Highways. The results of the geometric design visualized in the form of drawings using AutoCAD 2D. The design speed (Vd) set at 60 km/h with a horizontal arc radius of 358 m, a maximum slope of 4%, and an elevation (e max) of 8%. Based on these design criteria, a spiral curve with a circular arc length (Lc) of 74,996 m obtained. Then, the calculation results of the long vertical alignment of the PPV (L) of one type of concave curve are calculated.

1. Introduction

Roads are an essential means of transportation to connect various places such as industrial centers, agricultural areas, and settlements as well a means of distributing goods and services to support the economy (Purnama, Rifai, & Nasrun, 2022). Infrastructure development can be in the form of roads, toll roads, bridges, and others. Road infrastructure development can be in the form of supporting infrastructure for road development. Road infrastructure development has been carried out in several countries to meet the need for adequate roads. Increasing the number of roads proves the critical role of road infrastructure in the development of each country (Zulfa, Rifai, & Taufik, 2022).

Indonesia's rapid economic development has made traffic even more congested. Indonesia is currently home to more than 230 million people, and the country's economic growth has increased the demand for transportation and vehicle ownership (Ulchurriyyah, Rifai, & Taufik, 2022). Therefore, road infrastructure development is being intensively carried out in Indonesia to anticipate the booming traffic flow in an area. Highways are separated into National Roadways, Provincial Roads, Regency Roads, City Roads, and Village Roads following Law of the Republic of Indonesia No. 38 of 2004 and Government Regulation No. 34 of 2006 regarding the status of roads (Rizqi, Rifai, & Bhakti, 2022). Roads can also affect all economic activities in Indonesia. Indonesia'snational economy is expected to snowball after a decade of significant investment in public infrastructure projects emphasizing new roads, railways, ports, airports, power plants, distribution, water supply and sanitation, schools, and hospitals (Nugroho, Rifai, & Akhir, 2022). Thus the geometric planning of roads in Indonesia influences the productivity of road infrastructure development.

Majalengka City is currently building extensive road infrastructure. One of the existing infrastructure projects in Majalengka is the construction of the Cipali Toll Road. Due to the identified economic benefits, construction of toll roads in Indonesia under President Joko Widodo was carried out massively (Rahayu, Rifai, & Taufik, 2022). This infrastructure development is caused by various factors, including the construction of the West Java International Airport (BIJB), which is located in Kertajati, Majalengka. Road infrastructure development must support airport activities.

Jalan Siliwangi is a road located in Panyingkiran which is a link to the city. Road geometric design is road engineering that focuses on designing physical forms to fulfill road functions. In general, road geometry planning is done manually using drawing tools and mathematical techniques (Salsabila, Rifai, & Taufik, 2022). Road geometric planning can be performed using AutoCAD®2D software. The application of AutoCAD® technology in highway surveying and design has led to major changes in traditional highway design methods (Adiputra, Rifai, & Bhakti, 2022). Therefore, considering the effectiveness and efficiency of time, geometric planning on the Siliwangi road can use AutoCAD®2D software.

The purpose of this study is to plan the geometry of the Siliwangi Road in the western region of Majalengka. This planning to increase land transportation facilities and connect the Panyingkiran subdistrict to urban areas. The location has chosen to renew the road in this area titled "Road Geometric Design Used AutoCAD®2D: A Case Study: Jalan Siliwangi Majalengka, Indonesia". Based on the above problems, road redesign will be held precisely on Jalan Siliwangi for 4 KM. Horizontal and vertical alignment along 4 KM with manual calculations using AutoCAD®2D software. This research is expected to provide an efficient and effective highway geometric design solution.

2. Literature Review

2.1 Highway

Highways are a type of land transportation infrastructure that functions as a road between one road or region and another (Segui, Safhi, Amrani, & Benzaazoua, 2023). Those are several types of highways based on their functions, including arterial, collector, local, and environmental roads. The types of roads divided according to their conditions into main roads, provincial roads, district roads, city roads, and village roads.

n general, many highways in Indonesia experience problems. One of them is the congestion that occurs in big cities. Congestion is a common traffic issue in large cities. It can becaused by unfavorable road geometry. It necessary to analyze congestion and forecast future traffic models to prevent traffic congestion (Almatar, 2023). In addition, the many sharp turns on Indonesian roads make the number of accidents a bit high.

In Majalengka City, there are several main roads or national roads that face this problem. Highway authorities should prioritize improving the geometry of two-lane highways because they represent an essential road network component (Goyani, Chaudhari, Arkatkar, Joshi, & Easa, 2022). Therefore, there must be a good road geometric design such that the roads in Majalengka cities can run well or not have significant problems.

2.2 Road Geometric Design

Highway design involves designing roads to support the goals of society as a whole, including access to workplaces, colleges, businesses, and homes; accommodating multiple modes of transportation, such as walking, cycling, public transport, and vehicles; and minimizing fuel consumption. Using pollution and environmental damage (Afolayan, Abiola Samson, Easa, Modupe Alayaki, & Folorunso, 2022). The geometric design of a highway must consider several aspects. Highway geometric design is concerned with a physical and visible aspects of a highway, such as its cross-sectional elements, sight distances, alignment, curves, superelevation, and other related features (Kamble, et al., 2022).

The geometric design consisted of vertical orientation, horizontal orientation, and road sections. Care must be taken when planning or designing the geometric design of roads. Therefore, the planning and design of road geometric features, including horizontal orientation, vertical direction design, calculation of visibility distance, and horizontal and vertical radii of curvature, must be carried out with care (Nurjannah, Rifai, & Akhir, 2022).

The main objective of geometric design is to optimize efficiency and safety while minimizing costs and environmental damage (Chakole & Wadhai, 2022). With the development of this era, geometric design support tools are becoming increasingly sophisticated. Therefore, AutoCAD® Civil 3D and AutoCAD®2D software are generally used as geometric design support tools.

2.3 AutoCAD®

AutoCAD is an interactive drafting software package developed in the early 1980s by AutoDesk for the construction of objects on a graphics display screen (Jimoh, 2019). Currently, in addition to science and technology, software is also applied to art, architectural design, and structural design. Some of these software packages can perform multiple functions simultaneously, including the simultaneous integration of architectural, structural, and construction management elements (Gunawan, Rifai, & Irianto, 2022). This application is very commonly in civil engineering majors; at any university, it is always used as a basis for building design.

AutoCAD was developed and marketed by AutoDesk. AutoCAD is commonly used by industry, architects, project managers, engineers, interior designers, graphic designers, and another professionals (De Yong, Kusumarini, & Tedjokoesoemo, 2020). This version of the program is constantly evolving or being updated annually. However, every year there is some progress in the speed of project implementation, but the progressing is not very significant. This software can also be used to create or design the road geometry. Using AutoCAD®, design components, and volumes can be calculated in a short time for design a road plan (Nurjannah, Rifai, & Akhir, 2022).

This software is versatile in various fields and can combine several aspects, such as architecture, structure, and construction, to facilitate design implementation with workers. In addition, with the difference in the appearance of the building form displayed in the program, repairs can be performed quickly and efficiently (Onur & Nouban, 2019). In addition, this application can be downloaded on laptops with minimal storage, such as those with 2 GB of RAM. Of course, this software is also the basis for someone in the world of civil engineering. Therefore, the process of using this software is relatively easy to implement.

3 Method

Data are one of the main strengths in the preparation of research and scientific modeling. The data can also be used as a reference to determine the conditions in the area. The data used in planning this geometric design were obtained from Google Earth and processed into the global mapper and AutoCad®2D. This design planning starts from the Kadipaten sub-district to the Panyingkiran sub-district or JL. Siliwangi is 5.4 kilometers long.

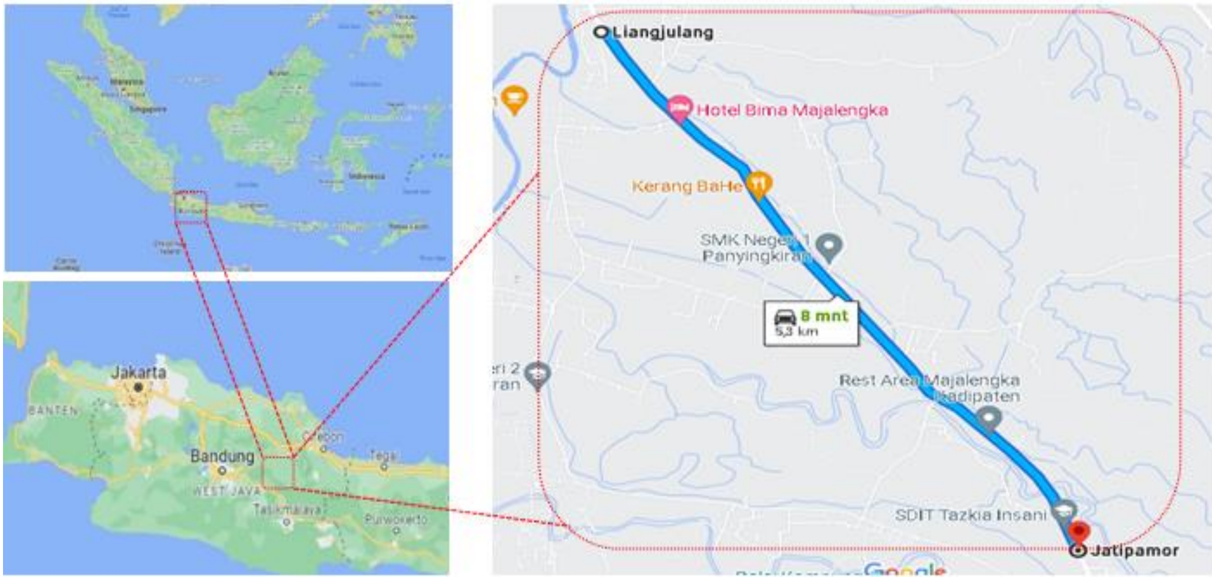

Figure 1. Research Location

A road geometric design plan certainly requires supporting data to obtain a job that is safe and efficient. The method used for the geometric planning criteria for this road was also quantitative and qualitative. Quantitative research methods are sourced from mathematical sample data to obtain road geometric planning results according to standards (Adiputra, Rifai, & Bhakti, 2022). Primary and secondary data are needed in this study.

Primary data has typically obtained through field observations. The observation method is a data collection technique that involves observing and recording the state of a target object (Oktobrianto, Rifai, & Akhir, 2022). Secondary data has been obtained from relevant sources without previous research or observations. The secondary data in this study is Google earth's topographical data. In addition, Google Earth data has been processing using a global mapping program. Subsequently, the data generated by the Global mapper is reprocessed in AutoCAD so that enough horizontal and vertical lines and paragraphs can be sees on the data. In addition, the standard design criteria used in this report refer to the road geometric guidelines provided in the 2020 Circular Letter of the Directorate General of Roads of the Ministry of Public Works and Public Housing. The geometric design results have been visualized in drawings using the AutoCAD® 2D program.

4 Result and Discussion

4.1 Design Criteria

The Siliwangi Road, which is located from the Kadipaten sub-district to the Panyingkiran sub-district in Majalengka Regency, is included in the primary class III local roads. The results of this study were based on the Road Geometric Design Guidelines (Directorate General of Highways, 2021).

Table. 1. Criteria Design

Road Name	Road Type	Road Functio n	Classificatio n	Plan Speed	Maximum Elevation(E maks)	Cross Error (f maks)	Width of Road
Jalan Siliwangi	2/2 UD	Primary Local	Hill	60 KM/hours	8%	0,17	3,50 m x 2

4.2 Horizontal Alignment

The following is the data obtained from the Siliwangi road section, which is used to calculate the horizontal alignment (spiral-circle-spiral). Jalan Siliwangi has classified as a primary local road with class III, and this terrain has flat terrain, so a design speed range (VD) has been obtained between 20 and 60 km/hour, as shown in Table 5.1 in the Guidebook for Road Geometric Design (Dirjen Bina Marga, 2021).

The first step was 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 value of the cross-sectional roughness (f max), calculated using equation (2).

$$R \min = \frac{V\hat{}2}{127(e\ maks + f\ maks)} \quad (1)$$

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

To calculate fmax in the equation above, that is, using the equation below, the value of the design speed (VD) 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 r min value in Equation (1), the next step is to calculate the transition arc length (Ls). The values required in this calculation include the value of the design speed (VD) = 60 km/h and the travel time, which is equal to 3.

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

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

From the above calculation, the minimum value of the transition arc length was 50 m. The Radius was 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) Guidelines for Road Geometric Planning (Dirjen Highways, 2021) so we 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 arc length (Ls) and minimum design radius (Rc).

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

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

The results of the above calculation 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) was calculated. Before performing the calculation, 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's known that the value of the horizontal circle curve (θc) is 11.9980, Subsequently, the value of the design curve (Lc) is calculated using the known c value 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 calculation, the Lc value was 74.996 and was proven to exceed 20 m. The total length (L) is obtained from the sum of the design curve values (Lc) with the 2 × transition curve values (Ls), both of which 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 observe that the total design arm length (L) is 174.996 m. The next step was to determine the spiral tangent (P) value using the transition arc length (Ls), design radius (Rc), and horizontal spiral curve (θs).

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

$$P = \frac{50^2}{6 \times 358} - 358\,(1 - cos 4{,}001) = 0{,}291 m$$

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

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

$$K = Ls - \frac{Ls^3}{40 \times 358\text{^}2} - 358 \times sin 4{,}001 = 24{,}954$$

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

The calculation above yielded an abscissa p on the spiral tangent (K) of 24.954. Subsequently, the next step is to find the value of the distance P1 to the circle (Es) using the value of the design radius, spiral tangent (P), and beta coefficient, all 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 angular distance (P1) to the circle was 6.808 m. Then, the value of the spiral tangent meeting point (TS) or spiral tangent meeting point (ST)has obtained. The values used are the plane radius (Rc), spiral tangent (P), beta coefficient (β), and abscissa value of p 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 seen in Equation (11) that the value of the point of contact of the spiral tangent line (TS) or the point of contact of the spiral to the tangent line (ST) is 87.535 m. After determining the value above, the relative slope have calculated by determining the width of the road (L), the length of the spiral curve (Ls), and the coefficient value (e).

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

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

After calculating all horizontal alignment components, the results shown in the following image:

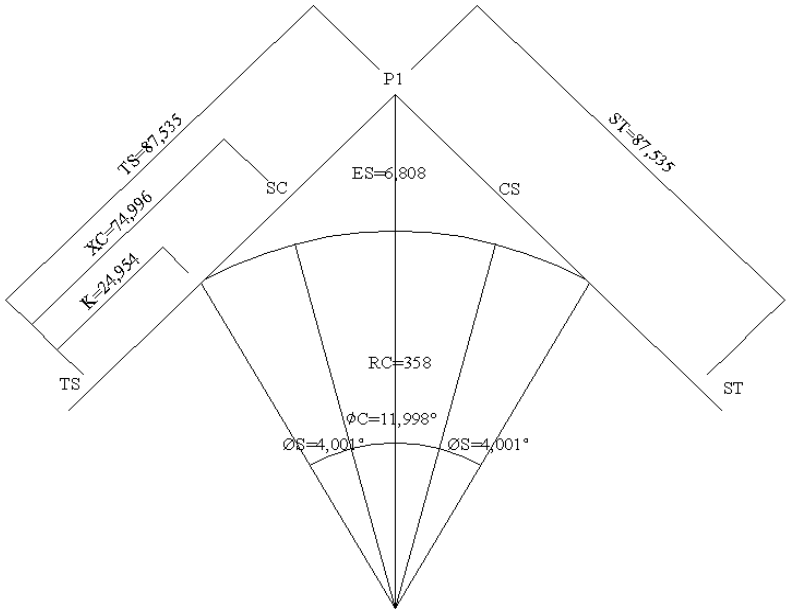

Figure 2. Horizontal Alignment

4.3 Superelevation Diagram

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

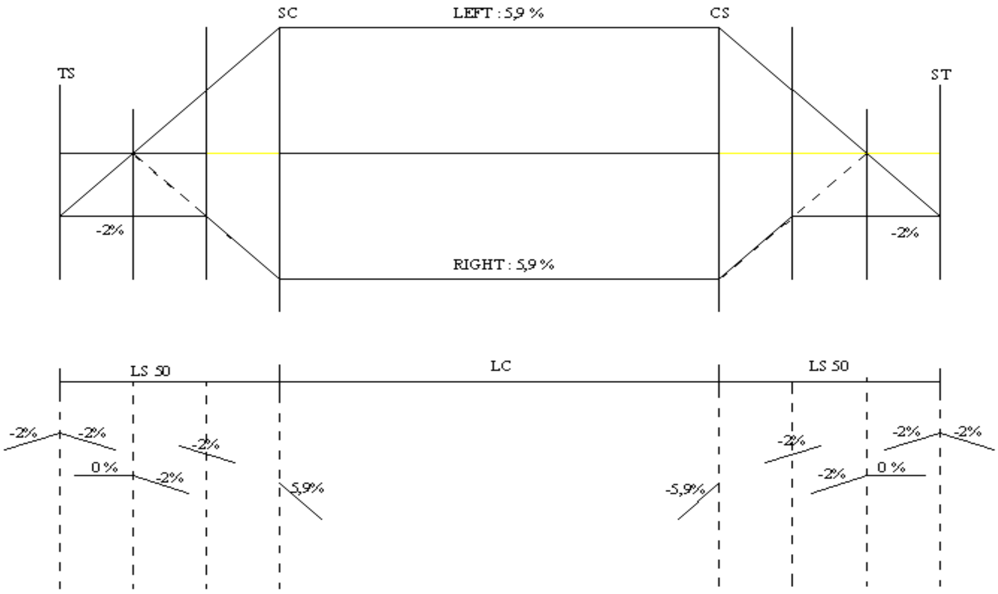

Figure 3. Superelevation Diagram

4.4 Vertical Alignment

The vertical alignment in this section was visualized using AutoCAD®2D along the Siliwangi Road from Sta 0+000 to Sta 5+400. A vertical-alignment image is shown in the image below.

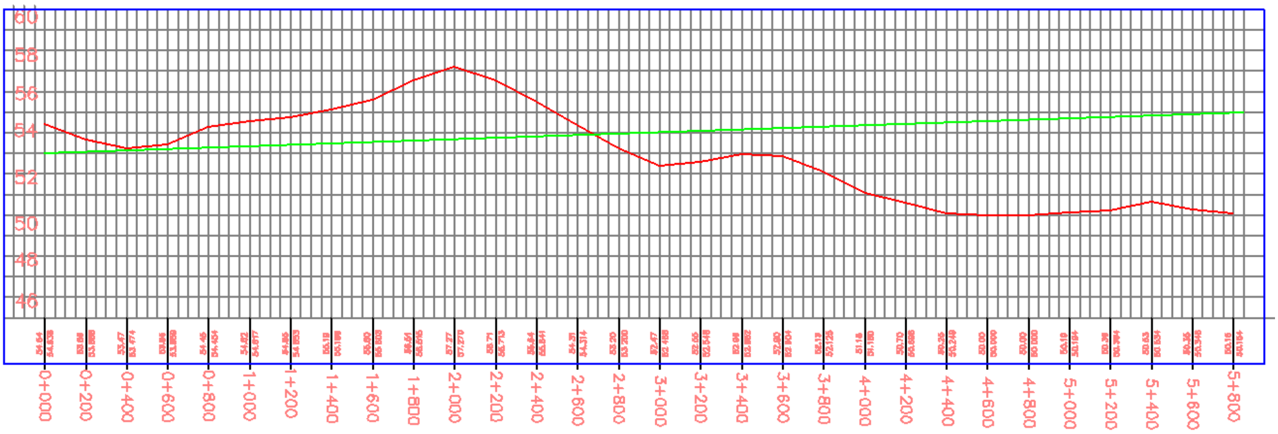

Figure 4. Vertical Alignment

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

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

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

$$g1 = \frac{elv.end - elv.PPV}{Sta.end - Sta.PVV} \times 100\% \tag{14}$$

$$g1 = \frac{53,00 - 58,00}{2.000 - 1.800} \times 100\% = 0,40\%$$

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

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

$$L = K.A \tag{16}$$

$$L = 16 \times (-0,40\%) = 64\,m$$

From the value of the vertical arc length (L), the value of the vertical displacement from the PPV point to the cross-section bending point can be determined using the calculation below.

$$Ev = \frac{AL}{800} \tag{17}$$

$$Ev = \frac{0,40 \times 64}{800} = 0,032\,m$$

$$X = \frac{1}{4} \times L = \frac{1}{4} \times 64 = 16\,m$$

$$Y = \frac{A.X\text{^}2}{200.L} = \frac{0,40.16\text{^}2}{200.64} = 0,008\,m$$

After searching for the above calculations, some data were obtained. The road slope (A) was − -0.4% (concave curve). In addition to these data, the value of the vertical arc length (A) is 64 meters. The vertical displacement from the PPV point to the bending point (elv) was 0.032 m. The X value is obtained from the data above, which is 16 m, whereas the Y value is 0.008 m.

5 Conclusion

Based on the results of the geometric design for Jalan Raya Siliwangi using the AutoCAD® 2D method and calculations according to the Road Geometric Guidelines (Dirjen Bina Marga, 2021) applied to one section of a road in hilly terrain. The design speed (Vd) set at 60 km/h, with a horizontal curve radius of 358 m, a maximum gradient of 4 n, and a maximum elevation (e max) of 8%. Based on these design criteria, a spiral curve with a circular arc length (Lc) of 74,996 m has obtained. Subsequently, The calculation results of the long vertical alignment on the PPV (L) of one type of concave curve were calculated at 64m.

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