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Road Geometry Planning on Horizontal Curves Using AutoCAD® Civil 3D: A Case of Mujahiddin – Lampok Road, Nusa Tenggara Barat

Bayu Endoriawan[1], Yusra Aulia Sari[2]
[1]Civil Engineering, Faculty of Engineering, Universitas Mercubuana, Indonesia
[2]Faculty of Civil Engineering & Planning, Universitas International Batam, Indonesia

Correspondence Email: baayyndr00@gmail.com

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ABSTRACT

Indonesia is a country that has a large forest area, making it famous for its wood industry. The wood industry is processed into various kinds of furniture to be exported to all cities and countries. The connecting road between Mujahiddin-Lampok Road is made to support the economic activities of residents as Copper and gold suppliers. This research aims to design road geometrics, especially horizontal alignments by the "2021 Road Geometric Design Guidelines". The road to be made starts from STA 0+000 to STA 1+423.75 with objective data in 2022 using the AutoCAD® 3D auxiliary program. This road planning uses quantitative data which is divided into primary and secondary data. From the calculation results it can be concluded that on the 1424 km long road 2 different types of curves can be applied. The types used are SCS and SS (Road geometric planning must consider cost efficiency and safety.

1. Introduction

Roads are one of the country's most critical infrastructures. With toll roads, all routes become more accessible and convenient, and travel distances are shorter and more efficient. Countries are competing to innovate in highway construction to improve driving safety. Expanding road infrastructure is an essential element of global conservation planning and development. History shows that highway motorists have always regarded driving speed, safety, and comfort as simple responsibilities, so it is only sufficient to ensure road safety programs are in place [1].

According to the Head of the NTB Provincial Public Works Office, Supardi Iskandar, NTB is classified as having minimal road infrastructure, especially on Sumbawa Island. He said, of the total length of national roads in the region (601 km), 14% of them were damaged. The worst damage occurred in West Sumbawa Regency. Meanwhile, on Lombok Island, Mataram, and its surroundings are in very good condition. This is an area in dire need of economic development to improve the standard of living and welfare of the people. To achieve this goal, the country needs various supporting factors, one of which is infrastructure, which increases along with the increase in economic activity. The consequence of changes in the development of a nation is a prerequisite for infrastructure [2].

With the advancement of technology, the current computation or design of geometric pathways should be replaced with software. The use of software in planning makes infrastructure development more effective and efficient as well as in terms of cost, time, and resources with current tools and software. The geometric design of roads can be done using AutoCAD® Civil 3D software [3].

Road geometry planning is inseparable from horizontal profile and curvature, including foot length, line and curve, superelevation curvature, and longitudinal profile, including ascent, descent, and slope. These parts are linked together to meet design requirements according to function and purpose of use. Now, line geometry planning has been designed and implemented more quickly due to current technological developments in the construction sector, which have had a significant impact and innovations continue to grow and evolve [4].

2. Literature Studies

2.1 Road Geometric Planning

Road design is an important part of transportation engineering. One of the main aspects of road design is geometric planning, which focuses on the placement of roads on topographic maps [5]. Geometric planning is part of road planning that focuses on the physical form so that the main function of the planned road can be fulfilled. The main function is to provide optimal service in traffic flow and access from one place to another. The geometric layout of a road has three fundamental parts: horizontal alignment, vertical alignment, and cross-section. These three essential parts when combined provide a three-dimensional format for the road [6].

A road geometry is a shape that represents a road and includes sections, longitudinal sections, and longitudinal sections. Other aspects related to the physical shape of the road. Road shape design is part of road design It focuses on designing the physical shape of roads so that usable road shapes can be generated. We realize speedy, smooth, safe, comfortable, and efficient transportation operations. the geometric pattern itself It consists of horizontal alignment and vertical alignment. Road geometry elements must be selected, sized, and positioned to meet design criteria such as visibility, vehicle stability, driver comfort, drainage, economy, and aesthetics [7]. When the city develops along express roads and highways the conflicts are even more evident and imply to such regions an increase in the number of accidents related to the lack of road safety. The prioritization of the road style intensifies the Barrier Effect and creates a hostile environment development of other forms of transport [8] [9].

Road geometrics can determine the shape of the driveway, such as curvature radius, deflection angle, spiral length, tangent length, and roadway/lane/shoulder width, and any or all of these can be customized by the designer [10] [11] [12]. Highways are supposed to provide users with comfort and safety, enable efficient traffic operations, and at the same time, charge the minimum possible cost in construction and maintenance [13] [14]. The purpose of geometric road planning is to fulfill the essential function of the road, namely to provide services for the movement of traffic flows (vehicles) with safeness and maximizes the ratio of usage rates and implementation costs [15] [16]. The pavement road layer is easily damaged by standing water due to the nature of the asphalt mixture. This condition is caused by the fact that asphalt has properties that are not too strong against water immersion [17] [18].

Geometric features considered in this section include essential horizontal and vertical alignment factors, including curvature and slope, and elements that make up the cross-section of the roadway, including lanes, curbs, and yards. Roadway design standards should feature a line geometry diagram, including design criteria, general rules, and procedures. Geometric design refers to the visible features of a road, making safety an important factor in road design, width, and passability [19]. Roads are also a means of transportation that has a very important role in life, including accelerating the economy and culture, the flow of distribution of goods and services, as connective access between one region and another, and improving the economy and standard of living of the community [20] [21].

2.2 AutoCAD® Civil3D

AutoCAD Civil 3D® is a Building Information Modeling (BIM) system application. Reduce time spent designing, analyzing, and implementing changes. AutoCAD® Civil 3D works fast and intelligent design program. This program uses a 3D model that dynamically updates the associated civilian design. changing elements. Programs can link design and documentation and contribute to growth. Improve productivity and quality of construction plans. This program is due to a design change that Minimizes captured elements in documents and minimizes manual updates [22] [23].

Three-dimensional (3D) reconstruction is the process of generating a 3D representation—a 3D view of the output from the data acquisition device. Image-based 3D reconstruction of civilians Infrastructure is a new topic with much interest in construction science and commercial area. Reliable computer vision-based algorithms are Over the past decade, it has become applicable to solving real-world problems in uncontrolled environments. Civil 3D allows you to create 3D models of your projects and helps you adapt them to small and large projects. In addition, 3D visualization helps you imagine things, saving you time and money [24]; [25].

The last one is useful for displaying the result of vertical and horizontal alignment calculations. Alignment calculations can be found in the Toolbox tab to view and export horizontal and vertical results. Click Report Manager. Click Alignment and Station, A curve resulting from a horizontal alignment calculation. Click Profile Profiles, PVI Stations, and Curves Alignment calculation result. Export to Microsoft Excel and validate with manual calculation results It gives the result of the alignment calculation [26] [27] [28].

2.3 Horizontal Alignment

They used Bayesian network analysis to predict the probability of vehicle collisions. Traffic and road factors and their impact on traffic accidents. It should be noted that the vehicle speed, Horizontal curve radius, vehicle type, adhesion coefficient, and fore/aft inclination are essential causes. Horizontal curve radius is calculated based on road collision probability results. The sill, grip factor, and roadside width are Vehicle speed and vehicle type for accident detection in dangerous areas on curves under review—research results for improving roadside safety in curved sections small radius. Therefore, vehicle speed and horizontal curve radius can also be estimated—an important factor in traffic accidents [29].

In horizontal alignment planning, it is necessary to consider the calculation of straight sections, superelevation, curves, degrees of curvature, transitional curves, and stationing. Horizontal alignment consists of straight lines connected by curved lines, 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 curve), or changeable (transition curve) [30].

3. Methodology

Data is one of the key strengths of scientific research and modeling (Rifai, Hadiwardoyo, [31]. A systematic scientific research process must start with identifying the right problem. Data is one of the strengths to combine scientific research and modeling. The primary data used in the study used data from Google Earth to determine coordinates. There are also secondary data on traffic levels made by previous researchers and other parameters according to applicable regulations [32].

The road planning site is located in West Sumbawa Regency, NTB. This journal uses qualitative research methods. The data used in this research are primary and secondary data. Primary data for this research is data in the form of horizontal curves. Secondary data includes condition maps, existing road geometry data, and road surface contours between the Mujahiddin and Lampok areas. This road geometric design uses AutoCAD® Civil 3D with several other supporting applications such as Google Earth, Global Mapper, and Microsoft Excel. The map of West Sumbawa is shown in the figure below, so using AutoCAD Civil 3D® can simplify the process and save time.

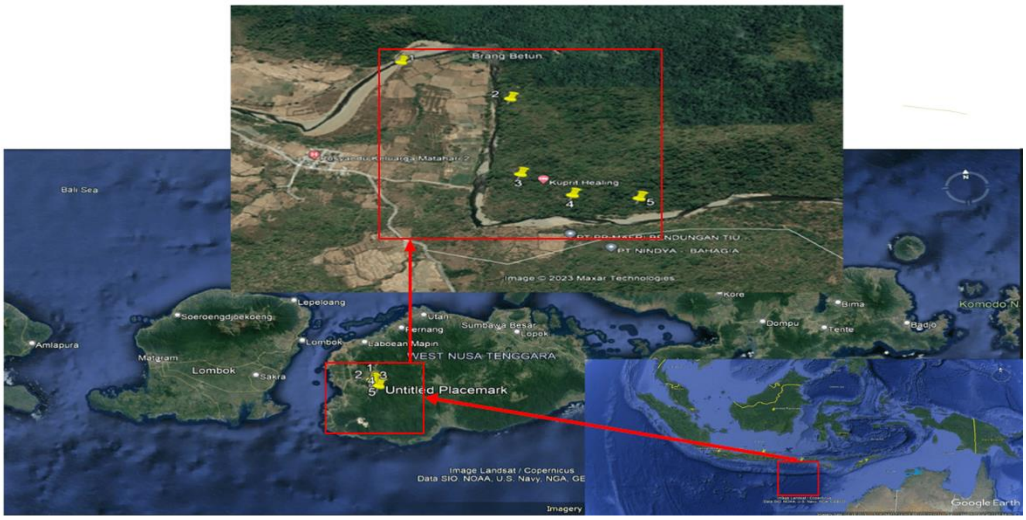

Figure 1 Road Mapping of Mujahiddin - Lampok

The first step in performing geometric road design is to determine a map of the area between the Mujahiddin and Lampok areas. Then from the map of the area, a surface or polygon will be created on Google Earth software that includes coordinate points to plan the road footprint. Next, the surface area will have its elevation obtained through the National Digital Elevation Model (Demnas). Then, using Global Mapper data, Demnas will generate ground contours. The ground contour is used as a reference to create a road trail from the coordinates of Mujahuddin (830681.00, 9207096.00) and Lampok (180309.00, 9213122.00). Suppose a road trace plan has been determined. In this case, the Horizontal Alignment is made by adjusting the flat ground contour.

4. Result and Discussion

4.1 Design Criteria

According to the 2021 Road Geometric Design Guidelines, the Mujahiddin-Lampok Road section is included in the local main road. Clarifying the design plan for the Mujahiddin-Lampok connecting road located on flat land with a 2/2 UD road type, 3.5 lane width, the plan speed is taken as 60 km/h with a maximum superelevation value of 6%. Specifically, the design criteria for the Mujahiddin - Lampok road can be seen in the Table 1 below.

Table 1 The Design Criteria for Geometric Planning Horizontal of Road Mujahiddin - Lampok

No.	Design Criteria	Value
1	Road Network System	Primer
2	Road Function	Local
3	Road Status	District Road
4	Road Class	I
5	Specifications for the Provision of Road Infrastructure	Moderate Road
6	Road Terrain Classification	Flat (< 10%)
7	Lane Configuration	2/2 UD
8	Velocity Design, V_D	60 km/hour
9	$Grade_{max}$	5%
10	Maximum Cross-sectional Roughness, fax	0.153
11	Normal Super-elevation, e_n	3%
12	Maximum Super-elevation, Emax	6%

The condition of the road in Mujahddin-Lampok can be determined by the structure of the largest vehicle that passes through the road. The largest technical vehicle in that context is the TMB, which is one of the large buses in local public transportation. According to the Road Geometry Design Guidelines (PDGJ), this road requires a minimum road width of 7 meters with a road type of 2/2 UD (undivided road with two lanes and two directions) and a width of each lane of 3.5 meters for large buses in local public transport.

4.2 Trace of the Road Geometric Desain

The Mujahiddin - Lampok Road trase will be planned to have two trases with the length of the trase starting from STA 0+000 - STA 1+423.75. Based on the road trace planning, coordinates of points, distances, and angles that have been obtained from AutoCAD Civil 3D®, the road trace to be made is the Mujahiddin-Lampok road trase.

Shown in Table 2 are the results of the resume from the calculation of coordinate points to get the azimuth angle, delta angle, and determination of the type of arc.

Table 2 Horizontal Alignment Coordinates

TITIK	KOORDINAT		JARAK			Azimuth	Sudut Tikungan
	X	Y	ΔX (m)	ΔY (m)	d (m)	α	Δ
Start	491753,706	9027974,783					
			-229,041	17,411	229,702	274,347	
1	491524,665	9027992,194					**31,649**
			-182,601	132,648	225,696	305,996	
2	491342,064	9028124,842					**48,447**
			-48,982	503,436	505,813	354,443	
3	491293,082	9028628,278					**52,221**
			-409,366	258,01	483,890	302,222	
End	490883,716	9028886,288					

4.3 Alignment Horizontal

Horizontal alignment is the projection of the road axis on the horizontal area, consisting of straight lines connected by curved lines. The road geometry orientation provided in the 2D plane to the center line of the road on the ground presenting the horizontal and vertical planes is called the alignment of the road. Horizontal alignment suggests the direction of the track and includes a straight path and curves (XY Cartesian plane) [33].

A local road planning project is to be built in West Sumbawa. The road in the construction area is a straight road with a slope <; of 10% with a maximum planned superelevation (emax) of 6%. The planned road function is a 2/2D local road (two lanes - two lanes) with a road width of 6 m and a planned speed of 60 km/h. The design value of curvature, which includes the determination of the minimum radius (Rmin) will be described in formula (1), and the transverse friction coefficient (F) of the plan speed is described in formula (2).

$$Rmin = \frac{V^2R}{127(0{,}01 \times e_{max} + f_{max}} \quad \text{......(1)}$$

$$f_{max} = -0{,}000625V_R + 0{,}19 \quad \text{......(2)}$$

Furthermore, the largest result is obtained based on the centrifugal force, relative landau, and travel time at Ls to obtain the LS max value. The max value of the comparison is taken from formula (3).

Based on the Centrifugal Force

$$Ls_{min} = 0{,}022\frac{V^3}{R.C} - 2{,}727\frac{V.e}{C}$$

Based on Relative Ramps

$$Ls_{min} = B.m(e + e_n) \quad \text{......(3)}$$

Based on Travel Time in LS

$$Ls_{min} = \frac{V}{3{,}6}T$$

The result of curved calculations on AutoCAD®Civil 3D are shown in the screenshot of Figure 2

No.	Type	Length	Radius	Design S...	Start Station	End Station	Delta angle	Chord length	Degree of Curv...
1	Line	260.697m		60 km/h	0+000.00m	0+260.70m			
2.1	Spiral-Cur...	54.000m		60 km/h	0+260.70m	0+314.70m	3.8675 (d)		
2.2	Spiral-Cur...	310.571m	400.000m	60 km/h	0+314.70m	0+625.27m	44.4861 (d)	302.829m	4.3659 (d)
2.3	Spiral-Cur...	54.000m		60 km/h	0+625.27m	0+679.27m	3.8675 (d)		
3	Line	202.165m		60 km/h	0+679.27m	0+881.43m			
4.1	Spiral-Spiral	77.000m		60 km/h	0+881.43m	0+958.43m	24.2234 (d)		
4.2	Spiral-Spiral	77.000m		60 km/h	0+958.43m	1+035.43m	24.2234 (d)		
5	Line	66.828m		60 km/h	1+035.43m	1+102.26m			
6.1	Spiral-Spiral	77.000m		60 km/h	1+102.26m	1+179.26m	15.8245 (d)		
6.2	Spiral-Spiral	77.000m		60 km/h	1+179.26m	1+256.26m	15.8245 (d)		
7	Line	151.289m		60 km/h	1+256.26m	1+407.55m			

Figure 2 Screenshot Result of Curved Calculations

This road construction uses the AutoCAD®Civil 3D program based on the contour data obtained, connecting Jalan Mujahiddin to Lampok as shown in Tabel 3, and is divided into several road planning destination points, starting from STA 0+000 and ending at STA. 1+423,75.

Table 3 Horizontal alignment calculation result

Bends	STA	Δ	Vr	Rc used	Rc	Ls	e	Control	Arch Type			Used
		(°)	(km/hour)	(m)	(m)	(m)	(%)	Ltotal	FC	SCS	SS	
P1	0+469.98	31.65	60	400	133.40	54.00	6	OK	NOT OK	OK	OK	**SCS**
P2	0+958.43	48.45	60	200	133.40	71.00	6	OK	NOT OK	OK	OK	**SS**
P3	1+179.26	52.22	60	200	133.40	71.00	6	OK	NOT OK	OK	OK	**SS**

In addition, the result of horizontal arch design in spiral-circle-spiral and spiral-spiral can be seen in Figure 3 below.

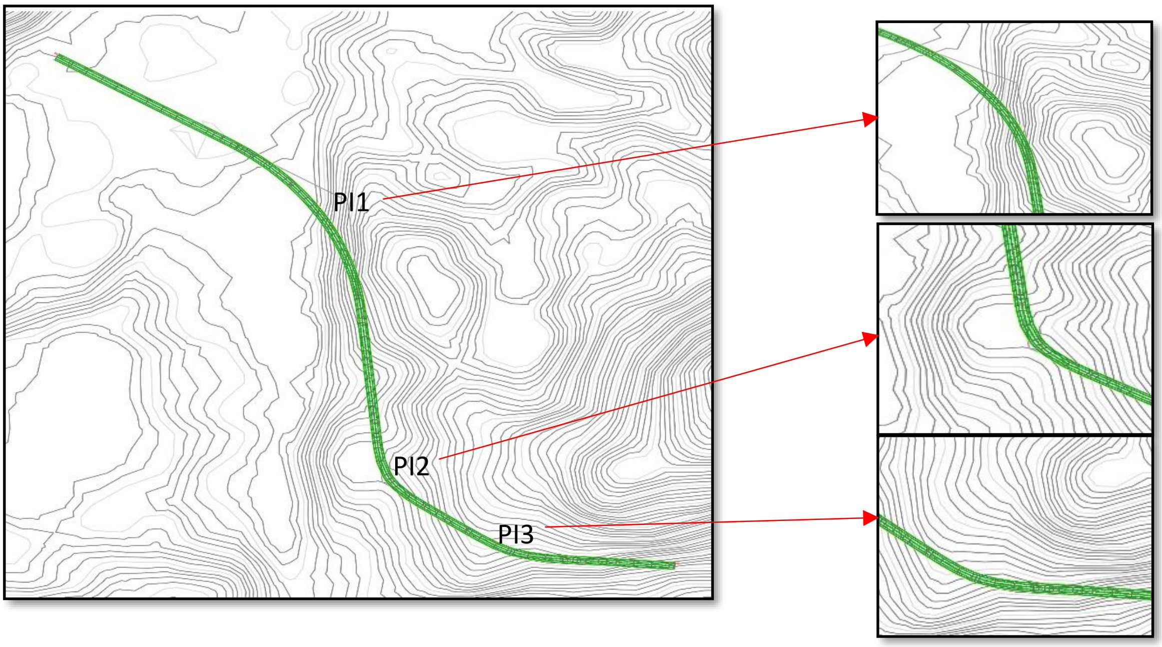

Figure 3 The Result of Horizontal Design

4.4 Superelevation Diagram

The superelevation diagram shows the change of superelevation value on a straight curve and a straight section along the curve. The overhanging design of the diagram aims to prevent the centrifugal force of the vehicle from rotating, to ensure safety and comfort when driving. Below are the Super Boost results and graphs of each projected angle. As shown in Figure 4

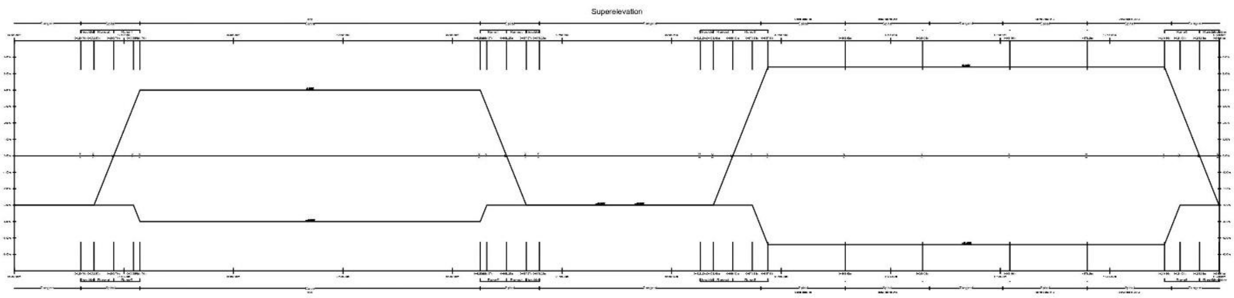

Figure 4 Superelevation Diagram

5. Conclusion

Several conclusions can be drawn from the horizontal alignment planning analysis of the alternative road between STA 0+000 and STA 1+423.75, which connects Mujahiddin-Lampok Road in West Sumbawa. According to the 2021 Road Geometric Design Guidelines, this road is categorized as an inter-city road and functions as a primary local road. The total length of this alternative road is 1424 km, consisting of three curves. The first curve is Spiral Circle-Spiral (SCS), while the second and third curves are Spiral-Spiral (SS). After performing the necessary calculations, it was determined that the Spiral Circle-Spiral (SCS) Type has a radius of 400 m and an arc length of 54 m. The Spiral-Spiral (SS) type has a radius of 200 m but an arc length of 71 m. Finally, the Spiral-Spiral 2 (SS) type has a radius of 200 m and an arc length of 71 m. It should be noted that all the planned horizontal curve points meet the requirements.

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