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# Geometric Planning of Horizontal Curved Road on Pagaralam – Tanjung Sakti – Bts Road Section, Bengkulu Province Using AutoCAD® Civil 3D

**Aziza Azahra[1], Ade Jaya Saputra[2]**
[1]Faculty of Engineering, Mercu Buana University, South of Jakarta, Indonesia
[2]Faculty of Civil Engineering & Planning, Universitas International Batam, Indonesia

E-corresponding: azizaazahra248@gmail.com

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***ABSTRACT***

*Road geometric planning is one of the conditions for road construction that aims to provide comfort, safety, and speed for road users. In the geometric planning of this road, the authors plan the geometric horizontal curved road on the Pagaralam - Tanjung Sakti road section at STA 0+000 - STA 2+450 located in Bengkulu Province using AutoCAD® Civil 3D. This study uses a quantitative method by taking data from Google Earth and Global Mapper. The steps in this study include terrain classification, road trace planning, horizontal alignment planning, design planning criteria, bend design, and superelevation diagram. The design results show that the Pagaralam – Tanjung Sakti road is secondary artery II, with a 2/2 TT road type. On this road section, the average slope of the Pagaralam - Tanjung Sakti road is 1.42%, and a geometric horizontal alignment designed with two bend designs using SCS (Spiral - Circle - Spiral) bend type with a radius of 550 m, Design speed (Vr) 80 km/ hours, maximum superelevation of 6% and a friction coefficient of 0.14.*

## 1. Introduction

The construction development industry continues to grow rapidly globally and is estimated to generate revenues of US$10.5 trillion / equivalent to Rp.151.334 trillion in 2023. Development is a change planning process that aims to improve various aspects of people's lives and as a benchmark for the development of a region. One example is the improvement of land transportation services, namely the construction of highways. Roads are infrastructure used to transport people or goods from one area to another. The road befit to guarantee the comfort and safety of its users, simplifies time, and is economical in its construction and maintenance [1]. Road construction is one thing that is always in line with technological advances and the thinking of the people who use it.

The first step is to explore and understand the basic understanding of a form of highway construction, namely road geometry. Road geometric planning included one of the requirements in road construction which aims to provide comfort, safety, and speed for its user. Road geometrics are extensively designed with stopping visibility models in mind, aiming to provide enough time to efficiently avoid accidents [2]. The geometric design of the road can divided into three main parts: horizontal drawing, vertical alignment, and sections, which together form the three-dimensional layout of the road [3].

In this all-digital era, all life activities are facilitated by the presenced of all-sophisticated technology. This technology exists to replace some of the past technology so that it can be more modern and also more practical. One of the technologies that can used in road geometry planning is AutoCAD® Civil 3D. This application is a BIM (Building Information Modeling) based Autodesk software thats capable of simulating all information in a development project into a 3-dimensional model that can produce plans

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in a shorter time, efficiently, and has a high degree of accuracy. [4]. It is use to produce 3D models of traffic, water, or land models maintaining relationships with source data such as contours, corridors, and classification [5].

In this geometry plan, the author uses Civil 3D to create a horizontal curvilinear road geometry for the Pagaralam - Tanjung Sakti - BTS section in Bengkulu Province. The purpose of building this road is to facilitate road traffic in the area and reduce travel time in the area to provide safety and comfort to road users.

## 2. Literature Review

### 2.1 AutoCAD® Civil 3D

In this modern era, transportation has an important role. One of the things related to transport is geometric planning. In geometric planning, there are horizontal and vertical curves, visibility, gradients, and intersections used well as the main indications that plann to prioritize security and safety [6]. In ancient times all designs were drawn manually with the help of tools. If geometric planning is done manually, it will take time, and cost a lot, the design is sometimes imprecise and there is only a 2D view. This problem has now been reduced by technological advances, where infrastructure planning is now widely planned with the help of computers [7]. One of them is AutoCAD® Civil 3D software.

AutoCAD® Civil 3D is a software project used to design construction projects, road construction, and water engineering, including the construction of dams, ports, canals, and embankments [8]. This software helps you realize projects faster, smarter, and more accurately because AutoCAD® Civil 3D software already uses the concept of dynamic modeling. It is a concept that automatically updates all related design processes when changes are made during the design process. AutoCAD® Civil 3D can also analyze the need for earthworks, fill and excavation, as well as analyze visibility, elevation, and validate data [9].

AutoCAD® Civil 3D allows you to create 3D project models and helps you implement them in small and large projects. It can help visualize things in 3D rendering, reducing time and budget [10]. With the AutoCAD® Civil 3D software, Many benefits are obtained and facilitate planning in construction and others.

### 2.2 Horizontal Alignment

Road accidents can caused by several factors, one of which is the imprecise geometric design of the road. The geometric design of the road has several parts, namely a horizontal design and a vertical design. Horizontal alignment is a flat road shape in a certain field, which can provide comfort, safety, or otherwise [11]. Horizontal alignment, commonly called arches, bends or turns by the people, is part of the road [12].

The horizontal alignment design has 2 (two) kinds of bends, namely Full Circle and Spiral Circle Spiral. Generally, two road sections are often encountered in road geometric planning, namely straight sections and curved sections or bends [13] [14] [15] [16]. In determining the alignment of a road, it is necessary to understand the topography of an area first. Because topography is the basis for determine the speed of the road plan to built and several other important aspects. Horizontal alignment was the first part of the geometric design of the road, which involves designing the curve of the road along its rails [17].

As for the length of the horizontal piece model, it is necessary to limit the possibility of neutralizing the monotonous and boring shape. If possible, the design of the horizontal part should be made straight with a larger bending radius [18] [19] [20]. Vehicles running on curved roads (bends) will receive centrifugal force. The sudden appearance of centrifugal force will cause a throwing force to the vehicle

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and its contents, which may cause the vehicle to skid and cause inconvenience to passengers. Therefore it is necessary to plan so that the magnitude of the centrifugal force that occurs does not exceed the centrifugal force that has been plan, and the dimensions of the centrifugal force that occurs increase slowly from zero to maximum (planning).

### 2.3 Road Geometric Planning

Highways are the main roads that connect an area/territory with other traffic areas/regions, mainly to ensure the continuity of distribution of goods and services. Road classification is an important aspect that must be identified before carrying out road planning. Because the design criteria for a road plan are determine from the design standards determined by the highway classification [21] [22]

Based on the Geometric Planning Procedures for Inter-City Roads, a road segment can be classified based on the review aspect, namely based on the service aspect, supervision, and funding aspect, and based on its function [23]. However, in everyday life, the division of road classes is not as evident as this concept. The purpose of the highway is as the principal infrastructure that supports land transportation and can support various human activities and needs in terms of mobility interests to achieve economic and non-economic goals. Geometric route planning is part of route planning. In the geometric design of roads, there are several rules and procedures for preparing road plans that meet the design criteria [12] [24] [25]This geometric design aims to combine the geometric design of intercity roads and create a road geometry that provides smoothness, safety, and comfort for road users. The geometric design of roads is a preliminary step in constructing connection or access roads. A connecting path is a path that connects the path to the goals with what already exists [26].

## 3. Methodology

Data is one of the main strengths in compiling research and scientific modeling [27]. In the geometric design of the road, the data collection method uses a quantitative research method by taking data from Google Earth and global mapper and then analyzing it with AutoCAD Civil 3D. The data is secondary data for this study.

Based on the data obtained, Pagaralam - Tanjung Sakti road is a class II (two) arterial road, so it is plan that vehicles passing are medium vehicles with a maximum axle weight of 10 tons. This road is locate in a flat and hilly area that consists of 2 lanes with the road contour data referred from Google Maps, Google Earth®, and Global Mapper®. The following is in Table 1. The planning criteria for horizontal alignment on the Pagaralam – Tanjung Sakti road are base on the 2021 Indonesian Road Design Standards.

Table 1. Road Data Planning

| Road Data | | |
|---|---|---|
| Location | Pagaralam – Tanjung Sakti | |
| LHRT Plan Year | 30.000 | SMP/day |
| Road Classification | Secondary Artery Class II | |
| **Design Criteria** | | |
| Road Function | Secondary Artery Road II | |
| Classification | Flat | |
| Road Type | 2/2 - TT | |
| Plan Speed | 80,00 | km/hours |
| Rumaja Width | 13,00 | meter |
| Rumija Width | 15,00 | meter |

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| | | |
|---|---|---|
| Ruwasja Width | 15,00 | meter |
| Lane Width | 7,00 | meter |
| Road Body Width | 11,00 | meter |
| Road Shoulder Width | 1,50 | |
| **Design Criteria** | | |
| Median Width | Without | |
| Maximum Superelevation | 6 | % |

Horizontal curved geometric planning that connects Pagaralam and Tanjung Sakti roads located in Bengkulu Province uses the AutoCAD Civil 3D method with the aim that road access in the area is smooth and can shorten travel time in the area to provide a sense of security and comfort for road users. The process of systematic scientific research must begin with the identification of a proper problem [28]. Road geometric design was take from STA 0000 to STA 2450. Design location in Figure 1. The data used for road design in this area comes from Google Earth and Google Maps.

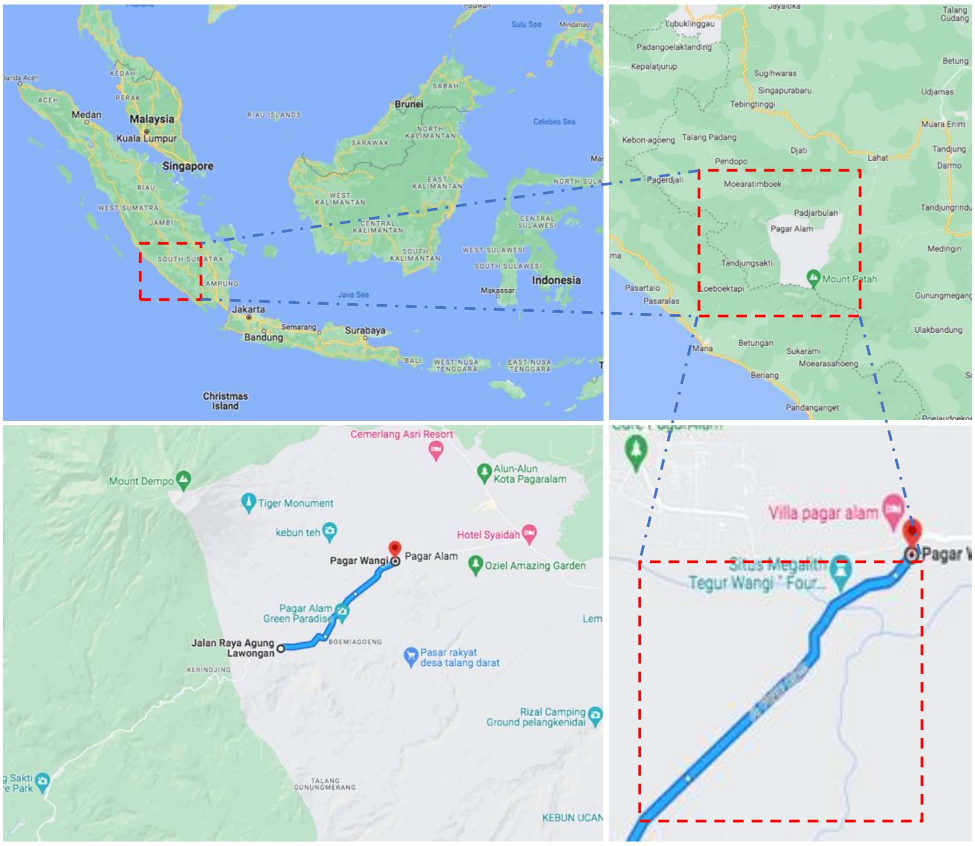

Figure 1. Location of Pagaralam – Tanjung Sakti

## 4. Result and Discussion

To process data on the Pagaralam – Tanjung Sakti road plan, especially the Horizontal Alignment, the author uses Autocad Civil 3D®. The following are the steps of geometric design based on current standards.

### 4. 1 Terrain Classification

Road terrain is classified based on the slope conditions of the road terrain. The following Table 2 classes the road terrain based on the PUPR regulations concerning the Road Geometric Design Guidelines 2021.

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Table 2. Classification of road terrain

| N | Terrain Type | Notation | Terrain Slope (%) |
|---|---|---|---|
| 1 | Flat | D | < 10 |
| 2 | Hilly | B | 10 - 25 |
| 3 | Mountains | G | > 25 |

The slope of the terrain is obtaine by making a new straight 25 m to the left and the right of the main track so that the distance between the new track points is 100 m. In Civil 3D, the height of the ground derived from both the terrain and the slope of each station, and the results of the slope of each station are obtaine using the following formula.

$$Kemiringan = \left|\frac{Elevation\ Left - Elevation\ Right}{Jarak\ antar\ titik}\right|$$

Based on the calculations using the above formula, the average grade of the Pagaralam - Tanjung Sakti road is 1.42%. A terrain slope of 10% is classified as flat terrain according to the Indonesian Highway Design Standard 2021 Interurban Road Geometric Design Regulations.

### 4. 2 Road Trase Planning

The Pagaralam – Tanjung Sakti Trace Plan, has two bends with distances starting from STA 0+000 – STA 2+450. The following Figure 2 shows the design of Pagaralam - Tanjung Sakti Trase Road.

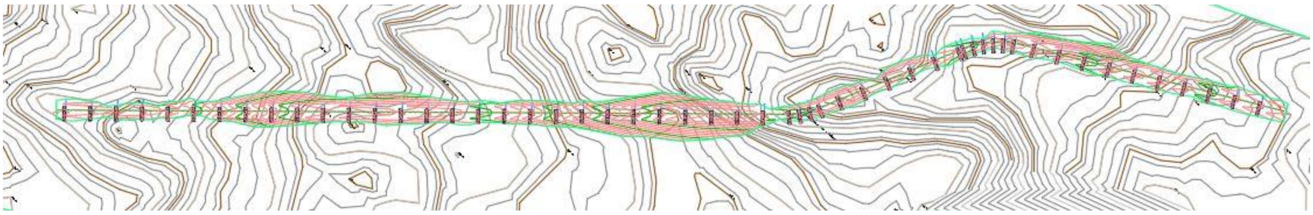

Figure 2. Pagaralam – Tanjung Sakti Trase Road

Table 3 is a road horizontal alignment plan in the form of coordinate points, the distance between points, and Corner PI from Civil 3D.

Table 3. Coordinate Points, Distance, and Corner PI from Civil 3D

| Coordinate Points | Distance | Corner PI |
|---|---|---|
| A = (301558.903 ; 9552746.367) | d A-1 = 586.79 m | Δ1 = 36.69 ° |
| PI1 = (301027.232; 9552498.067) | d 1-2 = 392.92 m | Δ2 = 22.76 ° |
| PI2 = (300841.134; 9552152.012) | d 2-B = 1444.03 m | |
| B = (299718.342; 9551243.949) | | |

### 4. 3 Horizontal Alignment Planning

The horizontal alignment geometry design consists of design bends and superelevations designed to compensate for the centrifugal force acceptable to vehicles traveling at design speed (VR).

### 4. 4 Design Planning Criteria

Based on the urban road geometry RSNI T-14-2004, the design criteria used in the Pagaralam – Tanjung Sakti road geometry design is a design speed of 80 km/h, a maximum elevation of 6%, a friction coefficient of 0.14 and a minimum radius of curvature of 229.06 m. Obtained bend range is 230 - 1300 m based on the relationship of horizontal curve design parameters with design speed.

### 4. 5 Bend Design

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The selection of the type of bend uses the AASTHO provisions, based on the AASTHO provisions spiral–circle–spiral bend components will be reviewe first. Considerations used in planning bends:

1. $R_{min}$ is 229.06 m, so planning uses R =230 – 1300 m
2. Given the double bend rules contained in the 2004 RSNI Urban Geometric Road regulations, the reversal multiple bend requirement has a minimum distance between two bends of 30 m as shown in Figure 3

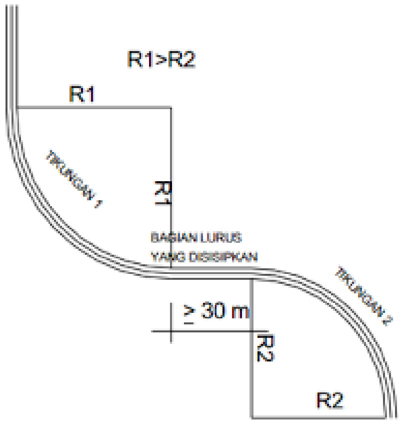


Figure 3. Bend Condition

The following are the usual steps to determine the bend radius used by knowing the bend components.

1. Specify the initial data, namely design speed, bend angle, normal clearance, the maximum clearance
2. Calculating Ls (Spiral Curve)
   a. Calculates Ls based on travel time

   $$Ls1 = \frac{v_r}{3.6} x\, T \quad (1)$$

   b. Calculating Ls based on the level of achievement of changes in slope

   $$Ls2 = \frac{(e_d - e_n) v_r}{3.6\, re} \quad (2)$$

3. Calculating components in horizontal alignment curves using SCS bends

$$\theta s = \frac{Ls}{2R}\frac{360}{2\pi} \quad (3)$$

$$\Delta c = \Delta - 2\theta s \quad (4)$$

$$Lc = \frac{\Delta c}{360} 2\pi R \quad (5)$$

$$Yc = \frac{Ls^2}{6R} \quad (6)$$

$$Xc = Ls - \frac{Ls^3}{40R^2} \quad (7)$$

$$k = Xc - R\, sin\theta s \quad (8)$$

$$Ts = (R + p)\tan\left(\frac{\Delta}{2}\right) + k \quad (9)$$

$$Es = \frac{R + p}{\cos\left(\frac{\Delta}{2}\right)} - R \quad (10)$$

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$$Ltotal = L + 2Ls \quad \ldots\ldots\ldots \quad (11)$$

4. Checking the Lc and p components to determine the type of bend used

$Lc < 25 \rightarrow SS \text{ and } Lc > 25 \rightarrow SCS$

$p < 0.2 \rightarrow FC \text{ and } p > 0.2 \rightarrow SCS$

Information:

$Ls$ = Transition arc length

$\theta s$ = Spiral curved corner

$\Delta$ = Bend Corner

$Lc$ = Circle arc length

$Xc$ = The abscissa point SC is on the tangent line

$Yc$ = Perpendicular distance to point SC on the arc

$p$ = Tangent shift to the spiral

$k$ = The abscissa of p is the tangent line of the spiral

$Ts$ = Tangent length from point PI to point TS or ST

$Ec$ = The distance between the PI point and the circular arc

From the formula above, it can be calculated and check the condition of the two types of bends that connect Pagaralam - Tanjung Sakti road, namely using the (SCS) Spiral-Circle-Spiral bend with a radius of 550 m. The following Table 4. a component of the calculation results for each bend.

Table 3. PI 1 and PI 2 Bend Corner Planning

| SUMMARY | | |
|---|---|---|
| Component | Bend P1 | Bend P2 |
| Δ | 36.697 | 22.766 |
| **R (m)** | **550** | **550** |
| **ed table (%)** | **5.40** | **5.40** |
| | | |
| Ls 1 (MRG) | 43.200 | 43.200 |
| Ls 2 (Table) | 74.000 | 74.000 |
| Ls 3 (GALA) | 0.000 | 0.000 |
| Ls 4 (Min, DC) | 51.381 | 51.381 |
| Ls max | 114.891 | 114.891 |
| **Ls design** | **100.000** | **95.000** |
| Check Ls` | **OK** | **OK** |
| | | |
| Ltr | **37.037** | **35.185** |
| Check Ltr AB/BC | **OK** | **OK** |
| Check Ltr CE | **OK** | **OK** |
| | | |
| Θs | 5.209 | 4.948 |
| Δc | 26.279 | 12.869 |
| Lc (m) | 252.262 | 123.534 |
| Yc (m) | 3.030 | 2.735 |

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| | | |
|---|---|---|
| Xc (m) | 99.917 | 94.929 |
| k (m) | 49.986 | 47.488 |
| p (m) | 0.759 | 0.685 |
| CEK p | OK | OK |
| Ts (m) | 232.647 | 158.354 |
| Es (m) | 30.259 | 11.734 |
| L total | 452.262 | 313.534 |
| | | |
| A | 234.521 | 228.583 |
| Check A | **OK** | **OK** |
| | | |
| d (A-PI1) | 586.794 | 392.921 |

After getting the calculations for each bend, enter the calculation results into Autocad® Civil 3D. Then in Figure 4 and Figure 5, the results of the bend design are obtained from Autocad Civil 3D.

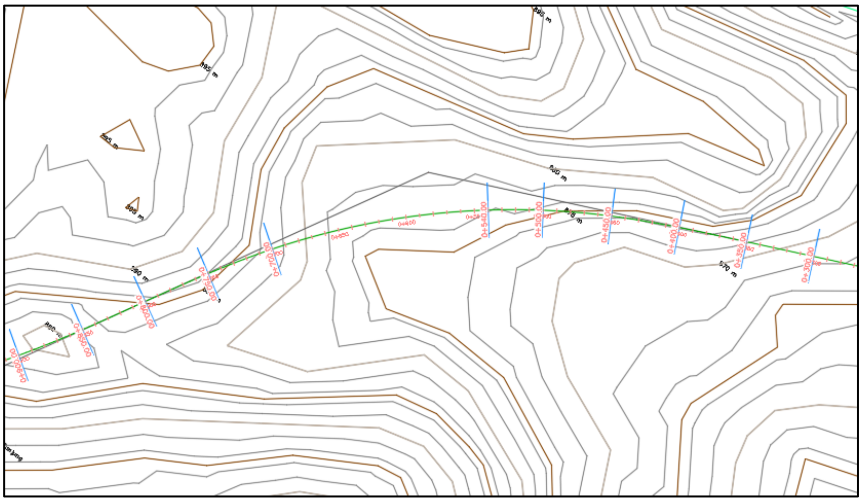

Figure 4. PI 1 Bend Corner Planning

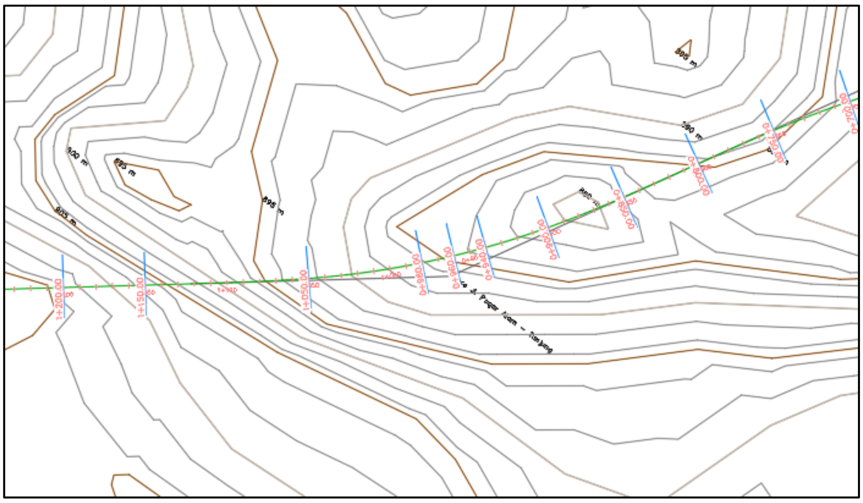

Figure 5. PI 2 Bend Corner Planning

## 4. 6 Superelevation Diagram

Superelevation diagrams depict changes in superelevation values on straight sections of curves, and straight along bends. The purpose of the superelevation design is to compensate for the centrifugal force

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that the vehicle experiences when cornering, providing safety and comfort while driving. The following in Figure 6 is the output of the superelevation diagram and stationing for each planned turn.

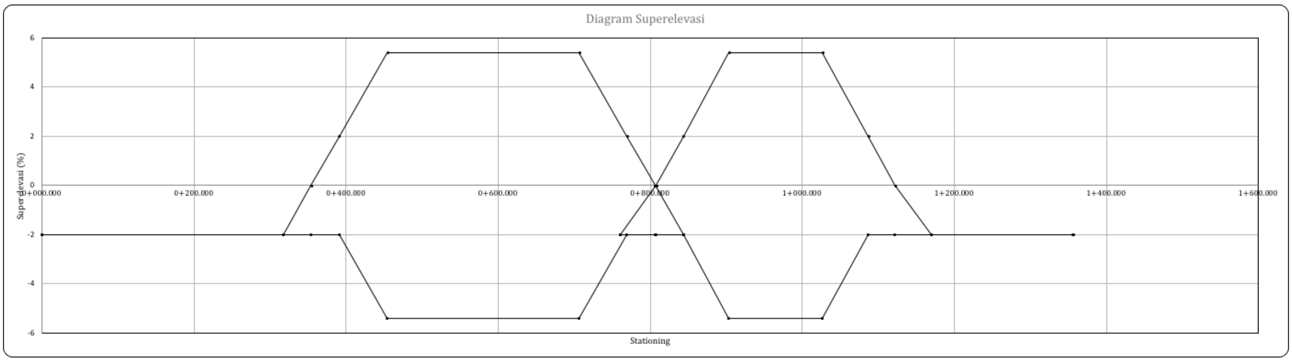


Figure 6. Pagaralam – Tanjung Sakti Road Superelevation

## 5. Conclusion

Several conclusions were reach from the results of the geometric design, calculations, and data processing done using AutoCAD® Civil 3D, namely the Pagaralam - Tanjung Sakti road is a class II (two) Secondary Artery road, with a 2/2 TT road type along 2.45 km at STA 0+ 000 –2+450. On this road a geometric horizontal alignment is designed with two design bends using the Spiral–Circle–Spiral (SCS) bend type with a radius of 550 m. Using AutoCAD® Civil 3D software can simplify road a geometric planning to obtain accurate data results.

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