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Geometric Design for Relocation of National Road Sei Duri-Mempawah Section, West Kalimantan using AutoCAD®2D

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Abstract

The International Port of Kijing is a National Strategic Project built as part of the Pontianak Port development. Therefore, it is necessary to design road geometrics to support the port's service level. This research proposes the relocation and geometric layout of the port of Kijing access road. The Sei Duri-Mempawah Section in West Kalimantan is where the data was collected. The design method used is SE PDGJ 2021 and finalized by AutoCAD®2D. The research results obtained design speed (Vr) = 60 km/hour, superelevation (e) = 8%, full circle horizontal curved type with the radius of curve design (R) = 500 m and intersection angle (β) = 35°, obtained horizontal arch length (Lc) = 305.37 m. Vertical alignment calculations are performed from the STA. 0+000 up to SAT. 1+400, we get a vertical curve (Lv) = 50 m and five vertical curves consisting of 3 crests and two sag curves.

Keywords: Access Road, Geometric Design, Port Access

1. Introduction

According to Presidential Decree No. 43/2017, the development of the Port of Dwikora Pontianak included building the International Port of Kijing, a National Strategic Project. The Port of Dwikora Pontianak, which accommodates 59% of West Kalimantan's container traffic on average and is growing at a 15% average annual pace, is the economic hub of Pontianak and the surrounding territories (Suryani, Permana, & Yunianto, 2019). The International Port of Kijing's presence is anticipated to lessen the pressure on Dwikora Port, which is currently highly heavy and challenging to grow owing to limited land (Sujendra & Eka, 2022).

A port must be able to interact with supporting areas (hinterland) to foster harmony between the local economy's many economic sectors to sustain a logistics system. Good transportation infrastructure and services may modify connections that affect logistics performance and improve a commodity's or product's competitiveness (Humang, 2018). Enhancing the quality of port access roads is one way to provide qualified transportation facilities as a supporting factor of logistics activities.

The International Port of Kijing is in Mempawah District, about 85 km from downtown Pontianak. The Sei Duri – Mempawah Road section is a national road connecting the Kijing International Port with Pontianak, Mempawah district, Singkawang district, and several other districts as port hinterland areas. The Sei Duri – Mempawah Road section is a National Road with class IIIB road (Ministry of Transportation, 2003), with the construction of the Kijing Port, will have the potential to cause changes in the performance of the Sei Duri – Mempawah Road section. As a result of performance changes of these roads and adjustments to the following International Port of Kijing's development plan, the existing road relocation will be carried out, and adjustments to road capacity (Riani, Said, & Kadarini).

The use of the software is needed to facilitate the geometric design. One of the supporting tools used in this research is the AutoCAD®2D program. AutoCAD®2D is a computer-based application that can create digital drawings with precise line drawings. CAD® software for 2D drafting allows creation of designs faster and more precisely without using stencils and technical drawing instruments. With this application, visualizing geometric designs can be done efficiently and informatively, especially in describing vertical and horizontal alignments (AutoDesk, 2022). This research carried out geometric planning for relocating the Sei Duri – Mempawah National Road Section. The design is to prescribe Vertical Alignment and Horizontal Alignment using the help of AutoCAD®2D software. This research is expected to get the results of appropriate and efficient planning.

2. Literature Review

2.1 Port Access Road

The port is the main intermodal structure in the logistics chain (Santos & Pereira, 2021). Where the movement of commodities from sea transportation modes to land transportation modes and the distribution of commodities to the consignee must be carried out efficiently and quickly. Therefore, the access road from the port to the city has an essential role in logistics distribution. Increased traffic flow often occurs in developed areas, causing congestion and an increase in vehicle volume. Therefore, Port access roads must have good traffic management and be supported by qualified access road facilities.

To control traffic, each port develops its access control system based on the functional layout of the port following appropriate governance and environmental restrictions (dos Santos & Hilsdorf, 2019). With varying characteristics, port access must accommodate the volume of vehicles entering and leaving the port because an increase influences the large volume of vehicles entering the port in commodities in an area. Therefore, the infrastructure supporting port activities with good service value is very important to support the pace of logistics in an area.

The road's status is divided into 5: national roads, provincial roads, regency roads, city roads, and village roads. The national road is a public road managed by the central government, which is then regrouped into Primary Arterial Roads, Primary Collector Roads, Toll Roads, and National Strategic Roads. Based on the status of the road grouping, it is divided into 5, namely national roads, provincial roads, regency roads, city roads, and village roads (Ditjen Bina Marga, 2021). The national road is a public road managed by the central government, which is then regrouped into Primary Arterial Roads; Primary Collector Roads; Toll Roads, and National Strategic Roads, as well as being included in the function of the Primary Arterial Road network.

2.2 Road Geometric Design

Road geometric planning is an effort to obtain a physical form of road infrastructure capable of fulfilling the essential functions of the road and providing optimal service, which can provide comfort and safety in road use and maximizes the ratio of the level of use of costs and environmental damage (Chakole & J.Wadhai., 2022). The geometric elements of the highway are obtained through several analyzes and calculations that are selected and positioned in such a way as to meet the road design criteria (Mandal, Pawade, & Sandel, 2019). Design criteria in geometric planning include cross-sectional elements, visibility, vehicle stability, driver comfort, traffic characteristics, and economic factors.

The appropriate geometric design can reduce the accident rate and the level of damage (Chakole & J.Wadhai., 2022). Therefore, the planning and design of the geometric features of the road, including the planning of horizontal alignment, vertical alignment, calculation of visibility distance, and determination of horizontal and vertical curvature radius, must be carried out carefully. Moreover, consider the future growth of traffic flows and the possible increase in higher road categories (Mandal, Pawade, & Sandel, 2019).

According to studies based on traffic volume, the number of accidents that occur is caused by vehicle speed, radius on horizontal curves/curves, lack of visibility, super elevations, and steep gradients (Chakole & J.Wadhai., 2022). proper alignment planning is critical. Alignment combines various design elements to create facilities that serve traffic safely and efficiently, consistent with the facility's intended function. Each element must complement another to achieve consistency, safety, and efficient design (AASTHO, 2018).

2.3 Sight Distance

Sight distance is the length of the road that is visible in front of the driver (Easa, 2003). This is an essential aspect of the design element from a safety point of view. Five basic types of visibility must be considered in the design: stopping sight, overtaking sight, decision sight, pre-view distance (on a horizontal arc), and intersection sight distance (AASTHO, 2018). Therefore, it can be concluded that planning the visibility according to the criteria can provide anticipation for the driver to see an obstacle and do something to avoid danger when driving.

Stopping Sight Distance (SSD) is one type of sight distance criterion that must be considered in geometric road planning. Stopping Sight Distance (SSD) depends on two main parameters, braking characteristics and the driver's reaction time (J.R, Samson, Hussain, K.M, & Alhajyaseen, 2022). The studies show that the SSD value is higher for wet road conditions than for dry roads. In addition, passenger cars that can go faster than large vehicles, such as trucks, have a lower SSD value. A higher deceleration rate can be achieved if the initial (before braking) speed is higher. More specifically, the research results can be used as input in the geometric design of highways under different situational aspects.

Sight distance is the distance along a highway at which an object of a certain height is continuously visible to the driver. This distance is determined by several criteria, such as the height of the driver's eye above the road surface, the height of a particular object above the road surface and the height of the object in the lateral position of the obstruction in the driver's line of sight. On a contoured road which is a barrier to the driver's visibility, it occurs at several points at the top of a vertical curve. In contrast, on a horizontal curve, it is a barrier to visibility, for example, trees, retaining slopes, and several other objects besides the road. Therefore, road construction planning must be taken into account both in the vertical and horizontal planes to estimate adequate visibility barriers for drivers (Congress, Puppala, Banerjee, & Patil, 2021)

2.4 Horizontal Alignment and Vertical Alignment

Design for the horizontal alignment of a road generally starts with making tangent lines that are interconnected on a topographic map or development map of an area (Roess, Prassas, & Shane, 2011). Choosing the correct route and following a field involves several important factors, including the selection of the correct route and following the terrain involves several important factors, including the estimated volume of vehicle requirements, the type of contour/topography of the area in question, watersheds, and environmental, social, and economic considerations.

A horizontal curve is designed to change the vehicle's direction at the center of the road. When a vehicle passes a horizontal curve, a centrifugal force will work out of the way through the vehicle's center of gravity which is influenced by the radius of the horizontal curve of a road and the speed of the vehicle itself (Phani, Veer, & Gupte, 2018). Several studies have confirmed that the road geometric planning index has an essential role in the event of an accident due to driver error, especially on the curve section of the road (Cheng, Cheng, Pei, & X, 2020). Therefore, based on the characteristics of the road, the more comprehensive the roadside will be able to reduce the possibility of accidental damage to the curved horizontal section. However, widening the roadside will affect the increase in vehicle speed.

Although the vertical alignment is the intersection of the vertical plane with the road work surface plane through the road axis in the vertical plane through the road axis (Robby, Riani, & Widiyatmiko, 2017). In designing the vertical alignment, efforts are made to adapt the road design to the existing topography. So that it can reduce the need for the cost caused by excavation work and the landfill (cut and fill) without compromising the safety value

To design horizontal alignment and vertical alignment, integration between the requirements and the applicable parameters must be carried out. A horizontal curve refers to how straight a road segment is, while a vertical alignment refers to the increase in pavement elevation or the flatness of a road (Latif, 2022). Integrating vertical and horizontal alignment into the design begins by defining corridors and the main boundaries that must be considered during the planning process. At the beginning of the planning process, planners must be able to align between the appropriate boundaries and combine vertical and horizontal alignments to produce road designs that achieve safety requirements and can be executed in the field.

2.5 AutoCAD®2D

AutoCAD®is a software developed in the early 1980s by the incorporation of Autodesk, which is used for object construction in a graphical display (Jimoh, 2019). AutoCAD®has an essential role in helping to simplify and visualize the results of designing an object into a graph or image that many people easily understand. This software is multi-functional in various fields and can combine several aspects, such as architecture, structure, and construction, to make it easier for workers to realize a design. Furthermore, with various perspectives from a building form seen in a program, it is possible to make repairs/upgrades quickly and efficiently (Onur & Nouban, 2019).

In this case, the use of AutoCAD®2D makes it easier to visualize the results of planning geometric elements in the form of working drawings. So that during the construction process, the engineers or implementers can easily understand the dimensions, elevation, and shape of the construction they are going to build. Furthermore, if an increase or design change is to be made, it can be done quickly by upgrading the design from the previous file.

In the engineering sector, using the software is very helpful in completing design work. In addition, AutoCAD® itself has an important role. This program helps in developing ideas and visualizing concepts through realistic rendering. AutoCAD® can be used to help calculate the components and volume of a design in a short time to plan road designs.

3. Methodology

Systematic scientific research must identify the right problem (Rifai, Hadiwardoyo, Correia, & Pereira, 2016). Data is one of the main strengths in conceiving research and scientific modeling (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015). Therefore, the research methodology used in this research is to process quantitative data obtained from the results of the observation method through observation and field surveys on research objects and the literature method by collecting literature, identifying, and processing the data obtained. This data collection is a step taken to conduct this research. The data obtained is according to the plan in the research so that it is precise and appropriate (Rifai, Anggreini, & Isradi, 2022). The research location is the access road to Port of Kijing, Sei Duri – Mempawah National Road section, in Mempawah District, West Kalimantan, as shown in Figure 1. Although this road is a National Road with class III-B road located in West Kalimantan province, ± 2.5 km of existing road sections were relocated as a new route of ± 5.6 km was created because the existing route became a Port Area development area, and a residential area for residents.

Secondary data was obtained from PT Pelabuhan Indonesia (Persero) as the project owner. The data used in this study are the topographic data of the existing road along with a situation map of the existing location. Data was collected from a topographical survey in October 2019. Parameters and other characteristic values will be taken from the applicable guidelines and regulations. The geometric planning for relocating the Sei Duri – Mempawah National Road was carried out using manual calculations regarding the Letter of the Ministry of Public Works and Public Housing of the Director General of Highways concerning the 2021 Road Geometric Design Guidelines. The calculation results of the geometric elements will then be visualized into drawings using AutoCAD® 2D.

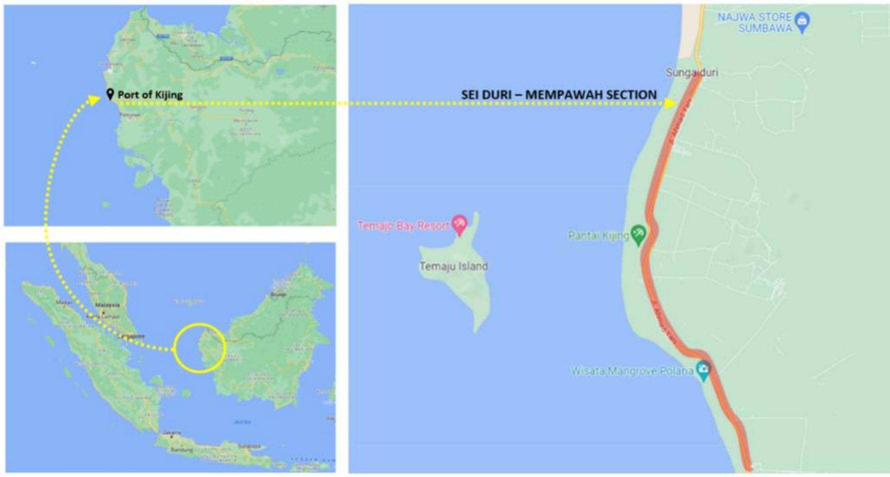

Figure 1. Research Location, Sei Duri – Mempawah Section

4. Result and Discussion

The road alignment design process is based on topographical data in the existing relocation area. Considered several factors such as security, comfort, and conditions of the area around the location. And with an average road slope below 3% (flat terrain conditions), the road alignment is designed as shown in Figure 2.

Figure 2. The Relocation Route Plan of Sei Duri – Mempawah Section

4.1 Horizontal Alignment Design

Design criteria for the Sei Duri – Mempawah road classified as a Primary Arterial Road and is a National Road with Road Class III and on flat terrain, the design speed range (V_D) is obtained between 60 – 100 km/hour as stated in Table 5.1 in the Road Design Standard of Indonesia (Ditjen Bina Marga, 2021). Therefore, the design speed (V_D) is taken as 60 km/hour. Based on Table 5.2 (p.45) with VD = 60 km/hour, the maximum superelevation value (e_{-max}) is 8%, and the graph in Figure 5-17 (p.96) then the side friction factor value is taken as 0.17. So that the minimum radius value for a horizontal curve can be calculated according to formula (1).

$$R_{min} = \frac{V_D{}^2}{127\,(e+f)} \quad \text{.......} \quad (1)$$

$$R_{min} = \frac{60^2}{127\,(0.08+0.17)} = 113.38 \text{ m; then designed R = 500 meters}$$

After obtaining the design radius of the curve (R), we can calculate the length of spiral (Ls) based on the travel time, where the value of the travel time (T) is 3 seconds with formula (2):

$$Ls = \frac{V_D}{3,6} x\, T \quad (2)$$

$$Ls = \frac{V_D}{3,6} x\, T = \frac{60}{3,6} x\ 3 = 50 \text{ meter}$$

The minimum length of spiral (Ls) can also be determined using table 5-32 (p.114), based on the value R=500 m; e_{-max} = 8%; with a road width of 3.50 meters and two lanes, the value Ls_{min} = 23 m is obtained. Then the longest Ls value can be taken, Ls = 50m.

Check the type of horizontal curve by calculating the value minimum lateral offset (p) at the bend using formula (3).

$$p = \frac{Ls^2}{24Rc} \quad (3)$$

$$p = \frac{50^2}{24\ x\ 500} = 0.208$$

Because the p-value ≤ 0.25 (Ditjen Bina Marga, 2021), the horizontal curve type can use the Full Circle type curve. Calculating the curved component of the full circle type will be done by taking one sample point calculation for the coordinates, as shown in Table 1, which is obtained based on a topographic map.

Table.1. Coordinates of Horizontal Curve

Point	X	Y
STA. 0+050	268.395,949	59.456,274
PI	268.355,876	59.288,897
STA. 0+400	268.424,413	59.114,051

By using AutoCAD®, the value of the intersection angle (β) of 35°, then we can determine the value of the tangent runout from TC-PI and PI-TC (Tc), the outer distance from the PI arc to the circular arc and the length of a circle (LC) as calculations on formulas (4), (5) and (6).

Tc = R x tan ½β .... (4)

Tc = 500 m x tan (½ x 35°) = 157,65 m

Ec = Tc x tan ¼β .... (5)

Ec = 157,65 m x tan (¼ x 35°) = 24,36 m

Lc = 0,01745 x β x Rc .... (6)

Lc = 0,01745 x 35° x 500 m = 305,37 m

Then the horizontal curve for the PI point and the superelevation diagram can be described in Figure 3 and Figure 4

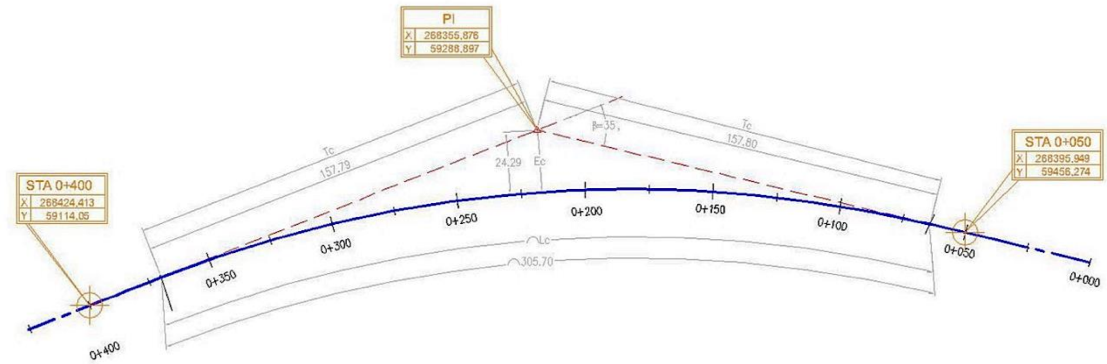

Figure 3. Horizontal Curve

In the bend area, the transverse slope of the road surface changes, namely from the whole slope, which changes gradually. Changes in the transverse profile can be carried out in three places: the road axis as the axis of rotation, the inner edge of the pavement as the axis of rotation, and the outer edge of the pavement as the axis of rotation. Straight-aligned roads require a typical transverse slope (e) = 2% for asphalt concrete for surface drainage. This includes the bend radius and the specified design speed. If the vehicle crosses a bend, the vehicle will undoubtedly be driven centrifugally.

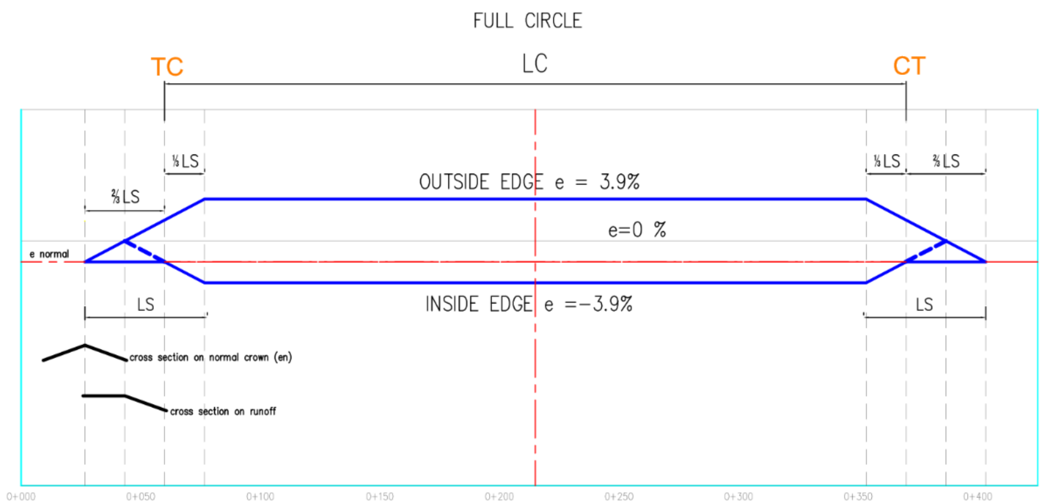

Figure 4. Diagram of Super Elevation

4.2 *Vertical Alignment Design*

The vertical alignment design will calculate from the STA. 0+000 to Sta. 1+400 along 1.4 km of the total relocation design of 5.2 km. The value of the design criteria is determined based on the Geometric Planning Procedures for Inter-City Roads (Ditjen Bina Marga, 1997). The maximum grade for the road with design speed (VR) = 60 km/hour is 8%, according to Table II.21. (p.36). Furthermore, the value of the comfort factor (Y) for the speed range of 40 – 60 km/h is three according to Table II.23 (p.37), so the value of the vertical arch length (Lv) and the vertical shift from the PIV point to curved section (Ev) can be calculated by formulas (7) and (8).

$$Lv = A \, . \, Y \quad \text{......} \quad (7)$$

$$Ev = \frac{A.L}{800} \quad \text{......} \quad (8)$$

Di mana:

Lv = length of vertical curve

Ev = Vertical shift to curve section

A = Algebraic difference of slope (g1 – g2)

Y = Comfort factor for 10 cm object and eye level on 120 cm

Table II.24 (p.38) determines the minimum vertical curve length, where the design speed range (VR) of 40 -60 km/hour can be determined Lv min between 40 - 80 meters. Then the calculation of vertical alignment can be done as follows:

Start Elevation	(STA. 0+000) =	3,000
PVI Elevation	(STA. 0+150) =	3,500
End Elevation	(STA. 0+200) =	3,500

$$g_1 = \frac{elv.PVI - start\ elv}{STA.PVI - start\ point} x100\% = \frac{3{,}500 - 3{,}000}{150 - 0} x100\% = 0{,}33\%$$

$$g_2 = \frac{end\ elv - elv.PVI}{end\ point - PVI} x100\% = \frac{3{,}500 - 3{,}500}{200 - 150} x100\% = 0\%$$

$$A = g_{1-}\ g_2 = 0{,}33\% - 0\% = 0{,}33\ (crest\ curve)$$

$$Lv = A \,.\, Y = 0{,}33\ \ x\ 3 = 0{,}99\ ;\ Lv < Lv\ min, then\ choose\ Lv \min = 50\ m$$

$$Ev = \frac{A.L}{800} = \frac{0{,}33\ x\ 50}{800} = 0{,}021\ m$$

Henceforth the above calculations will be applied to other coordinate points on the topographic map between STA 0+000 to STA 1+400, which are presented in Table.2

Table.2 Vertical Curve Calculation

Station	Elevation	Distance (m)	g1 (%)	g2 (%)	A	Type	Lv(m)	Ev
0+000	3,000	150						
0+150	3,500		0,33	0,00	0,33	Crest Curve	50	0,021
0+200	3,500	200						
0+450	3,500	100						
0+550	3,500		0,00	0,36	-0,36	Sag Curve	50	-0,023
0+825	4,500	275						
0+550	3,500	275						
0+825	4,500		0,36	0,00	0,36	Crest Curve	50	0,023
0+900	4,500	75						
0+900	4,500	100	0,00	-0,36	0,36	Crest Curve	50	0,023

Station	Elevation	Distance (m)	g1 (%)	g2 (%)	A	Type	Lv(m)	Ev
1+000	4,500							
		275						
1+275	3,502							
1+000	4,500							
		275						
1+275	3,502		-0,36	0,00	-0,36	Sag Curve	50	-0,023
		125						
1+400	3,500							

The following depiction of the vertical curve on the Sei Duri – Mempawah STA section. 0+000 to Sta. 1+400 with a vertical scale of 1:50 as shown in Figure 5. There are 5 vertical curves along the 1.4 km long research object consisting of 3 crest curves and 2 sag curves, with a vertical curve length of 50 m and a tangent displacement value (Ev) ranging from 0.021 – 0.023 as shown in Table 2

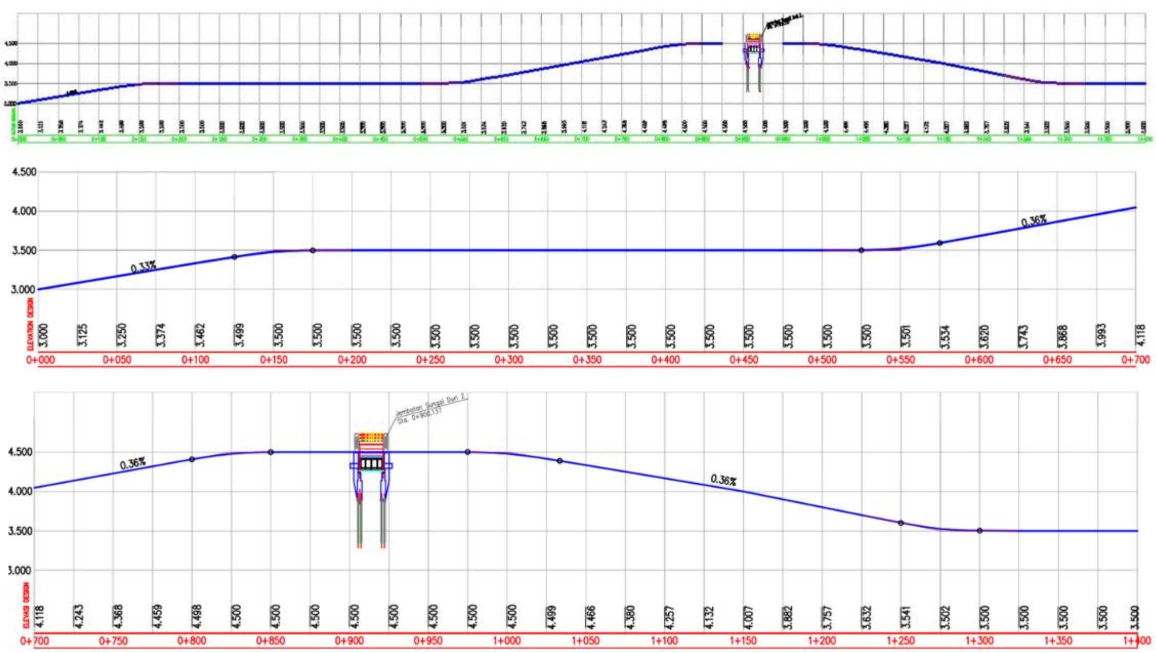

Figure 5. Vertical Curve on Longitudinal Section STA.0+000 – STA.1+400

5. Conclusion

The Sei Duri – Mempawah road section is a Primary Arterial Road with class III-B with a width of 2 x 3.5 meters. With the design parameters design speed (V_R) of 60 km/hour, the maximum slope (e) is 8%. From the calculation, the design radius (R) is 500 m, and the type of horizontal curve is full circle type, with the angle of intersection (β) = 35°, the length of the horizontal curve (Lc) = 305.37 m is obtained. Horizontal alignment calculations are carried out by taking curved curve samples at STA.0+050 to STA.0+400. In vertical alignment, calculations are made at STA.0+000 up to STA1+400. The section has five vertical curves consisting of 3 crest curves and two sag curves. With a vertical curve length of 50 m and a tangent displacement value (Ev) ranging from 0.021 to 0.023%. Road alignment design depends on the topography and condition of the area around the designed area. Therefore, determining the correct geometric parameters will directly affect the shape and type of road to be designed, affecting road service improvement. The relocation of the Sei Duri-Mempawah national road, as access to the Kijing International Port, is expected to be able to provide good service in terms of safety and comfort to support economic growth in the area around the port.

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