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ROAD GEOMETRIC FEASIBILITY IN ROAD SAGARANTEN – TEGALBULEUD KM.BDG 175 + 100

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ABSTRACT

The Sagaranten-Tegalbuleud road is a provincial road, with its geographic and topographic conditions quite complicated, the terrain quite difficult, causing not all areas to be well connected, and the reason for the low level of accessibility of this area. Therefore, determining the road geometry is an important part of driving comfort. Geometric planning focuses on horizontal and vertical alignments so that it can fulfill the basic functions of the road that provide optimal traffic flow comfort according to the planned speed. A re-survey was conducted to obtain geometric data on existing roads that did not comply with DGH standards, then it was re-planned. The results of the analysis are three bends with the Spiral-Circle-Spiral type, namely bend 9, bend 10 and bend 11 with RC = 17 m, and the slope is determined for the vertical geometrical alignment of the road. The results of this research analysis can be used as a reference for improving geometric roads so that accessibility between regions can be increased.

Keywords: roads; geometric; alignment; Bina Marga; traffic.

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INTRODUCTION

Roads are one of the most widely used transportation infrastructures to support the economy and daily human activities. The highway serves to pass the traffic above it quickly, safely, and comfortably (Muhammad et al 2020). Land transportation is the largest and most attention-grabbing transportation system. This is mainly due to human activities generally carried out on land, where this land transportation system requires road infrastructure as a connecting route to support the economy, regional development, social development, and cultural development (Bambang et al. 2018).

Geometric road planning is part of road planning that focuses on horizontal and vertical alignment so that it can fulfill the basic functions of the road which provide optimal comfort in traffic flow according to the planned speed (Muhammad et al. 2020). In general, geometric planning consists of aspects of road alignment planning, road bodies consisting of road shoulders and traffic lanes, bends, drainage, road slopes, and excavations and embankments. The purpose of road geometric planning is to produce a safe infrastructure, efficient service traffic flow, and maximize the ratio of usage/implementation costs. (Silvia Sukirman, 2010).

The Sagaranten-Tegalbuleud road is a provincial road which is one of the roads with quite complicated geographic and topographical conditions, which is the reason for the low level of regional accessibility. This difficult situation has resulted in not all regions being connected properly and optimally. The low level of accessibility is also caused by the low level of road stability, the minimum quantity and quality of transportation facilities, especially the coverage of public transportation services, so that the movement of people and goods becomes slow and limited (Herman Fithra 2017).

Based on these problems, it is necessary to evaluate the existing geometrical conditions of the road on Jalan Sagaranten - Tegalbuleud KM.BDG 175 + 100, then re-plan based on the standards of Bina Marga, namely the Geometric Planning Procedure for Inter-City Roads. The results of the re-planning analysis can be used as a reference for improving geometric conditions based on standards from DGH by policymakers and road managers.

Research purposes

1. Evaluation of existing geometric conditions with the status of provincial roads on Jalan Sagaranten - Tegalbuleud KM.BDG 175 + 100.
2. Redesigned STA 0 + 350 - 0 + 650, Sagaranten-Tegalbuleud Road Section KM.BDG 175 + 100, Sukabumi Regency.

Classification of roads in Indonesia according to Bina Marga in the Geometric Planning Procedure for Inter-City Roads No. 038/T/BM/1997, ie:

1. Classification According to Road Functions
   a. Arterial roads, namely roads that serve major transportation with the characteristics of long-distance travel, high average speed, and efficient restrictions on the number of entrances.
   b. Collector roads, which are roads that serve collector/divider transports with the characteristics of moderate travel, moderate average speed, and limiting the number of entrances.
   c. Local Roads, namely roads that serve local transportation with the characteristics of short-distance trips, low average speed, and the number of entrances is not limited.

2. Classification According to Road Class
   Under Article 11, PP. No.43 / 1993 regarding classification according to road class concerning the ability of roads to accept traffic loads, expressed in terms of the heaviest axle load (MST) in tonnes.

3. Classification According to Road terrain
   Road terrain is classified based on the condition of most of the slope of the terrain measured perpendicular to the contour lines, as shown in Table 1.

Table 1. Classification According to Road terrain

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

Source: Classification of the Road Law No: 38 of 2004 and PP 34 of 2006

In road geometric planning, the factors that influence, among others:

1. Vehicle Plan
2. Plan Speed
3. Topography

Roads with good geometric planning will get good results in accordance with predetermined planning standards. So that the geometric that is created will make the wearer more comfortable. This driving comfort is the main key in road geometric planning (A.Juang et.al, 2020); (S.Syaiful, D.Hariyadi, 2019); (S.Syaiful, L.Lasmana, 2020).

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Alinyemen Horizontal

In general, horizontal alignment planning will find two types of road sections, namely straight and curved sections consisting of three types of bends that are used, namely the circle (Full Circle), Spiral Circle Spiral and Curved Spiral - Spiral (Silvia Sukirman. 2010). For example, as a circle (Full Circle) as in Figure 1.

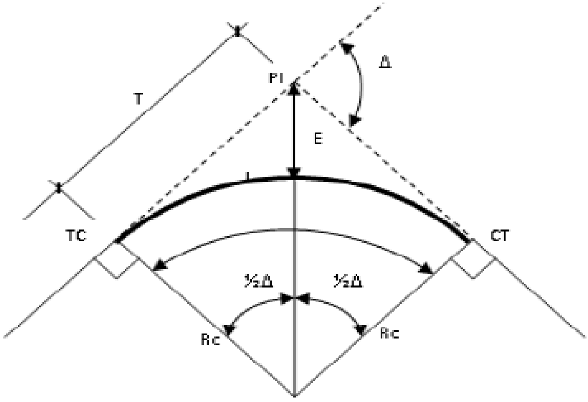

Figure 1. Full Circle Curve

Information:

Δ = Bend Angle
O = Center Point Circle
Tc = Tangent length distance from TC to PI or PI to CT
Rc = Circle radius
Lc = The arc length of the circle
Ec = Outer distance from PI to a circular arc

The transitional curve is made to avoid sudden changes in alignment from straight to circular, so this transitional curve is placed between the straight and the circle (circle), namely before and after the bend in the form of a circular arc (Heri Sutanto 2018). The transitional arch length (Ls), according to the Geometric Planning Procedure for Inter-City Roads, 1997, the largest value is taken from the three equations below:

a. Based on the maximum travel time (3 seconds), to cross the transitional arch, the length of the curve:

$$Ls = \frac{VR}{3,6} x\ T \quad (1)$$

b. Based on the anticipated centrifugal force, the short modification formula is used, namely:

$$Ls = 0,022\ x\ \frac{VR^3}{Rc\ x\ C} - 2,727\ x\ \frac{VRxe}{C} \quad (2)$$

c. Based on the level of achievement of slope change,

$$Ls = \frac{(em-en)}{3,6\ x\ re} x\ VR \quad (3)$$

Information:

T = Travel time (3 seconds)
Rc = Circle radius (m)
C = Change in acceleration, 0.3-1.0, recommended 0.4 m/s
Re = The level of achievement of changes in the cross-section of the road
VR ≤ 70 Km / hour then maximum re = 0.035 m / sec
VR ≥ 80 Km / hour then maximum re = 0.025m / sec
e = Superelevation
em = Maximum superelevation
en = Normal superelevation

If you get Lc <25 m, then the S - C - S shape should not be used, but an S - S curve is used, which is an arc consisting of two transitional curves.

Horizontal curves in the form of spirals are curved without a circular arc so that the point SC coincides with point CS. The chosen radius of Rc must be such that the required Ls is greater than the required Ls resulting from the required relative slope (Rozi et al 2017). Curves Spirals are not good bends because there is no certain distance in the same bend period. For these spirals, the following formula applies:

$$Lc = 0 \text{ dan } \theta s = \frac{1}{2}\Delta \quad (4)$$

$$Ltot = 2\ Ls$$

$$\theta s = \frac{90}{\pi} x \frac{Ls}{Rc} \quad (5)$$

$$Ls = \frac{\theta s\ x\ \pi\ x\ Rc}{90}\Delta \quad (6)$$

Vertical Alignment

Vertical alignment is the planning of the elevation of the road axis at each point in the form of a longitudinal profile (Bambang et al. 2020). In the vertical alignment planning, there will be a positive slope (incline) and a negative slope (derivative), so that the combination is convex and concave curves. Besides the two curves, there is also slope = 0 (flat). This condition is influenced by the topography traversed by the planned road route. Topographic conditions not only affect horizontal alignment planning but also affect vertical alignment planning (Geometric Planning Procedures for Inter-City Roads).

1. Ramps
   There are several things to consider and plan the vertical curves, namely:
   a. Maximum road grade
      The maximum road slope determined for various variations in the design speed is intended so that the vehicle can continue moving without losing significant speed.

   b. Minimum ramp
      On roads that use a curb on the edge of the pavement, it is necessary to make a slope of min. 0.5% for the need for a side-channel slope, because the cross-slope of the road with curb is only enough to drain water sideways

   c. Critical Length of a Slope
      This Critical Length is needed as the limit for the maximum slope length so that the reduction in vehicle speed is not more than half the VR.

Vertical Curve

A vertical curve is a transect formed by a vertical plane through the axis of the road. It is planned to change gradually the change two kinds of ramps that extend along the road at each required location (Procedure for Geometric Planning of Inter-City Roads / TPGJAK)

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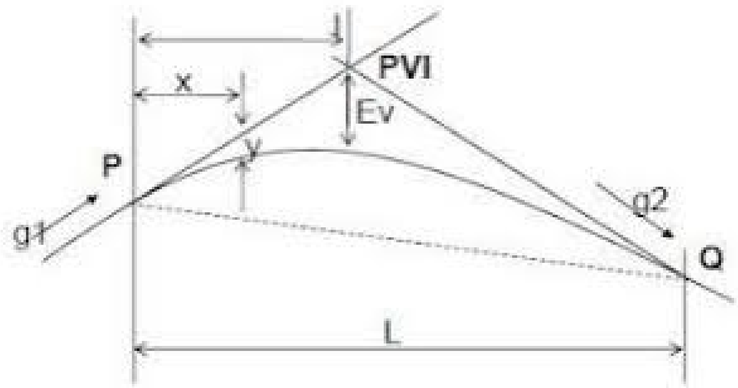

Figure 2. Vertical Curve

$$\text{Slope (\%)} = \frac{E.The\ end - E.The\ beginning}{Jend - JbeginningJ.End - J.Beginning} x100\%$$

RESEARCH METHOD

The research site is located on the provincial road Sagaranten - Tegalbuleud KM 175 + 100, Tegalbuleud sub-district, Sukabumi district. The research was carried out for 45 calendar days from 7 September 2020 to 6 November 2020 (5 days a week) starting from location surveys, measurement data collection processes, measurement data processing results, modeling processes, long road geometric analysis calculation processes, and making research reports. The research stages are briefly described in Figure 3.

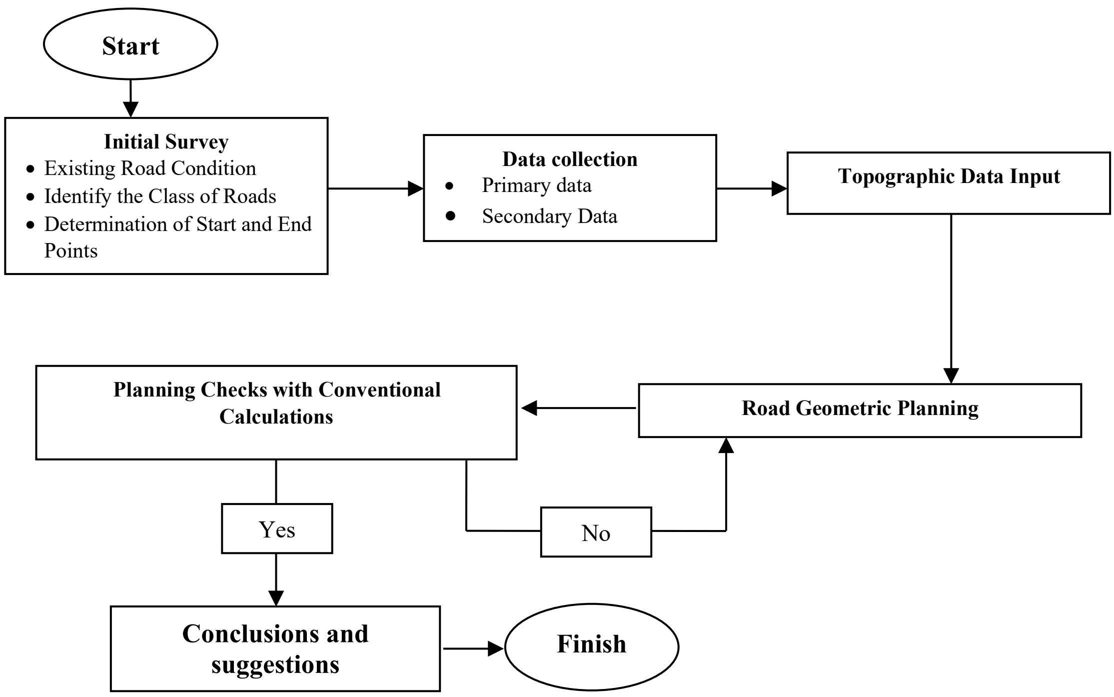

Figure 3. Research flow

RESULTS AND DISCUSSION

The road section Sagaranten - Tegalbuleud KM.BDG 175 + 100 STA 0 + 350 - STA 0 + 600 consists of 3 bends with a radius that does not meet the standards of Bina Marga, this can be seen in the description of measurement results in the field. By entering topographical data into the Civil3D program, the shape of the Sagaranten - Tegalbuleud KM.BDG 175 + 100 road is obtained which corresponds to the existing road in the field as in Figure 6.

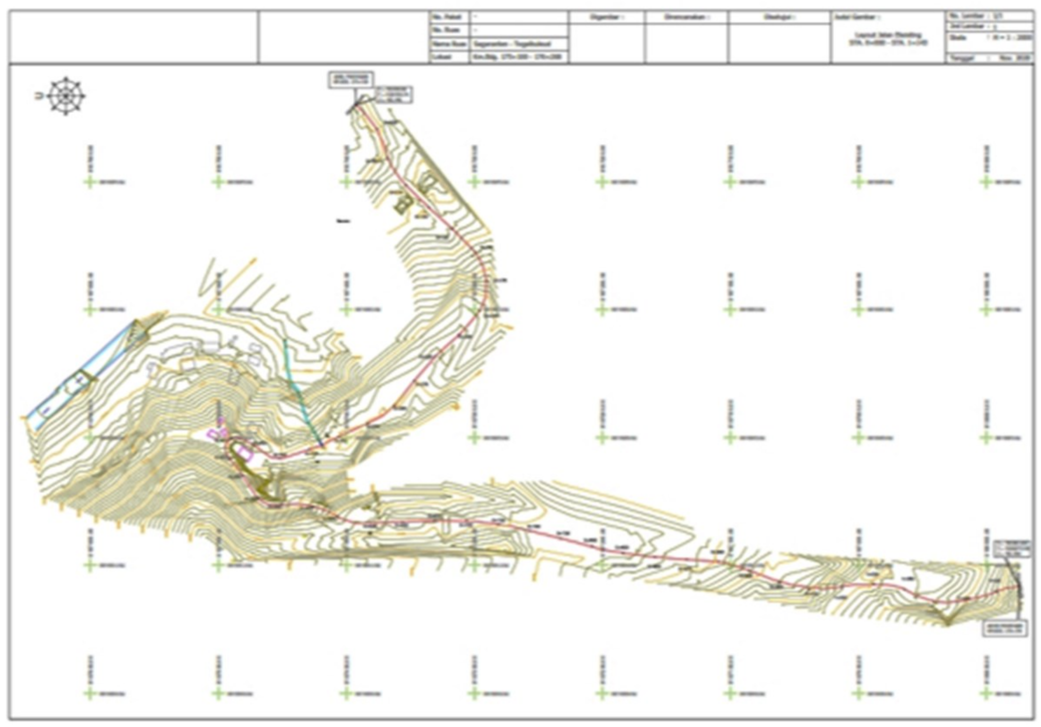

Figure 4. Existing Road on Jalan Sagaranten - Tegalbuled BDG 175 + 100

The existing condition will be re-evaluated by referring to the Standard for Geometric Planning for Inter-City Roads by Bina Marga 1997. The length of the existing road is based on measurement results along 1,118 km. After the analysis is made there are 19 curves with different radii, 3 of which have a radius less than Rmin = 15 m for a design speed (VR) = 20 Km/hr, that is, at curvature 9, 10, and 11, therefore the authors plan horizontal re-alignment and count conventionally.

Determining the road planning alignment, of course, before planning the speed to be redesigned. Based on the Geometric Planning Procedure for Inter-City Roads (TPGJAK), road speed (VR) is determined according to the road terrain classification. Furthermore, determining the transitional curve according to the Geometric Planning Procedure for Inter-City Roads (TPGJAK, 1997) which has been described in the literature review section. The following is the conventional calculation of the 3-point curve analysis plan.

1. Calculation of Curved Points 9

Curve point 9 is in mountainous terrain with coordinates 53 º59 58 '52 "and includes the function of the local road, then the planned speed is 20 km/hour with a radius of at least 15 m and a max. 10% superelevation plan:

V_R = 20 km/hour
R_{min} = 15 m
R_R = 19 m (take planning)

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e_{maks} = 10% = 0,1

Δ $= \frac{53 + 58 + 52}{3} = 54$

The width of the road = 3 m

Distribution Method

V $= V_R \, x \, 0{,}9 \; = 20 \, x \, 0{,}9 \; = 18 \; Km/Jhour$

fmax $= \; 0{,}192 - (0{,}00065 \; x \; 20) \; = \; 0{,}179$

Dmax $= \frac{181914{,}038 \; x \; (e_{max} + \; f_{max})}{{V_R}^2} = \frac{181914{,}038 \; x \; (0{,}1 \; + \; 0{,}179)}{20^2} = 126{,}885$

DPI $= \frac{181914{,}038 \; x \; (e_{max})}{{V_R}^2} = \frac{181914{,}038 \; x \; (0{,}1)}{20^2} = 56{,}146$

hPI $= \frac{(e_{max}) \; x \; {V_R}^2}{V^2} - e_{max} = \frac{0{,}1 \; x \; 20^2}{18^2} - \; 0{,}1 = 0{,}023$

S_1 $= \frac{hPI}{DPI} = \frac{0{,}023}{56{,}146} = 0{,}00042$

S_2 $= \frac{fmax \; - hPI}{Dmax - DPI} - = \frac{0{,}179 \; - 0{,}023}{126{,}885 - 56{,}146} \; = 0{,}002$

Mo $= \frac{((\; DPI \; x (Dmax - DPI)) x (S2 - S1))}{2 \; x \; DP1} = \frac{((\; 56{,}146 \; x (126{,}885 - 56{,}146)) x (0{,}002 - 0{,}00042))}{2 \; x \; 56{,}146} =$
0,028

D $= \frac{1432{,}394}{R_{plan}} = \frac{1432{,}394}{19} = 75{,}389$

e+f $= \frac{D \; x \; {V_R}^2}{181914{,}038} = \frac{75{,}389 \; x \; 20^2}{181914{,}038} = 0{,}166$

f = D < DPI

$= Mo \; x (\frac{D^2}{DPI})^2 + \; (DxS1) \quad : \; Mo \; x \left(\frac{Dmax - D}{Dmax - DPI}\right)^2 + \; hPI + (S2 \; x \; (D - DPI))$

$= 0{,}028 \; x (\frac{75{,}389^2}{56{,}146})^2 + \; (75{,}389 x 0{,}00042) : 0{,}028 \; x \left(\frac{126{,}885 - 75{,}389}{126{,}885 - 56{,}146}\right)^2 + 0{,}023 +$
$(0{,}002 \; x \; (75{,}389 - 56{,}146))$

= 0,082 : 0,081 → D>DPI then the smallest one is taken → 0,081

e $= (e + f) - \; f \; = 0{,}166 - \; 0{,}081 \; = 0{,}085$

a. Design Transitions

R_{min} $= \frac{VR^2}{127 \; x \; (e+f)} = \frac{20^2}{127 \; x \; (0{,}1 + 0{,}175)} = 11{,}45 \rightarrow 12 \; metre$
(Radius check = $R_{plan} > R_{min}$ =19 > 12 = OK !!!!

e_{design} = 0,085

Relative Slope = 50 m (comparison in table 5)

Ls (T = 3 second) $= \frac{VR}{3{,}6} xT \; = \frac{20}{3{,}6} x3 = 16{,}67$

Ls (SHORTT formula) $= 0{,}022 \; x \; \frac{VR^3}{Rc \; x \; C} - 2{,}727 x \frac{VR \; X \; e}{C}$

$= 0{,}022 x \frac{20^3}{0{,}4 \; x 19} - 2{,}727 x \frac{20 \; X \; 0{,}085}{0{,}4} = 11{,}537$ m

$LS_{slope\ change}$ $= \; emax - 0{,}02 \; x \frac{VR}{3{,}6 x 0{,}035}$

$= \; 0{,}1 - 0{,}02 \; x \frac{20}{3{,}6 x 0{,}035}$

$= \; 12{,}698$

LS_{design} = Ls (T=3 second) : LS SHORTT : $LS_{slope\ change}$
= 16,67 : 11,537: 12,698
= 16,67 (Maximum) →17 m (rounded off)

Check LS_{design} = $LS_{design} \leq 0{,}25$

$= \frac{LS^2}{24\ x\ Rplan} = \frac{17^2}{24\ x\ 19}$ **= 0,634 ≤ 0,25** → It takes a spiral !!!

b. Full Circle

TC	$= R_R x (Tan\ 1/2\ \Delta)$
	= 19 x (Tan ½ 54) = 9,683 m
EC	$= T_C x (Tan\ 1/4\ \Delta)$
	= 9,683 x (Tan ¼ 54) = 2,325 m
LC	$= \frac{\Delta\ x\ 2\ x\ \pi\ Rc}{360^0}$
	$= \frac{54\ x\ 2\ x\ 3{,}14\ 19}{360^0}$ = 17,898 m
Cek LC	= LC > Lcmin (VR = 20 km/hour = 40 m (**table 6**))
	= 17,898 > 40 m → It Takes A Longer Fingers !!!!

c. Spiral – Circle – Spiral (S-C-S)

Ls	= 17 m
Ɵs	$= \frac{LSx90}{\pi\ x\ Rr} = \frac{17\ x\ 90}{3{,}14\ x\ 19} = 25{,}632^0$
Ɵc	$= \Delta-(2\ x\ \Theta s) = 54 - (2\ x\ 25{,}632^0) = 2{,}743^0$
LC	$= \frac{\theta c\ x\ \pi\ Rc}{180^0}$
	$= \frac{2{,}743\ x\ 3{,}14\ x19}{180}$ = 0,91 m
Ltot	= Lc + (2 x Ls) = 0,91 + (2x17) = 34,91 m
P	$= \frac{LS^2}{6\ x\ Rr} - (Rr\ x\ (1-(\cos \emptyset s))$
	$= \frac{17^2}{6\ x\ 19} - (19\ x\ (1-(\cos 25{,}632))$ = 0,664 m
K	$= Ls - \frac{Ls^3}{40\ x\ Rr^2} - (Rr\ x \sin \emptyset s)$
	$= 17 - \frac{17^3}{40\ x\ 19^2} - (19\ x \sin 25{,}632)$ = 8,44 m
Es	= ((Rr + p) x (1/cos ½ Δ)) – Rr
	= ((19 + 0,665) x (1/cos ½ 54)) – 19 = 3,07 m
Ts	= ((Rr + p) x tan ½ Δ))) – k
	= ((19 + 0,665) x tan ½ 54))) – 8,44 = 18,46 m
Cek LC	= 0 > LC < 20
	= 0 > 0,91 < 20 → **Using Spirals – Spirals (S – S)**

d. Spiral – Spiral

Ls min	= 17 m
Ɵs	$= \frac{\Delta}{2} = \frac{54}{2} = 27^0$
LS	$= \frac{\theta S\ x\ \pi\ x\ Rr}{90} = \frac{27\ x\ 3{,}14\ x\ 19}{90}$ = 17,91 m
Ltotal	= 2 x Ls min = 2 xm 17 = 34 m
p	$= \frac{LSmin^2}{6\ x\ Rr} - (Rr\ x\ (1-(\cos \emptyset s))$
	$= \frac{17^2}{6\ x\ 19} - (19\ x\ (1-(\cos 27))$ = 0,464 m
K	$= Lsmin - \frac{Lsmin^3}{40\ x\ Rr^2} - (Rr\ x \sin \emptyset s)$
	$= 17 - \frac{17^3}{40\ x\ 19^2} - (19\ x \sin 27)$ = 8,33 m
Es	= ((Rr + p) x (1/cos ½ Δ)) – Rr
	= ((19 + 0,464) x (1/cos ½ 54)) – 19 = 2,845 m
Ts	= ((Rr + p) x tan ½ Δ))) – k

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= ((19 + 0,464) x tan ½ 54))) – 8,33 = 17,95 m

1. Superelevation diagram

a. Full Circle (FC)

Run out Length (RoL) $= Ls \times \frac{0,02}{0,02 \times e} = 17 \times \frac{0,02}{0,02 \times 0,085} = 3,23$ m

Run off Length (RfL) = Ls – Run off Length = 17 – 3,23 = 13.77 m

% Run off $= \frac{\left(\frac{2 \times LS}{3}\right) - RoL}{RfL}$

$= \frac{\left(\frac{2 \times 17}{3}\right) - 3,23}{13,77} \times 100 = 58,84$ %

b. Spiral – Circle - Spiral (S – C - S)

Run out Length (RoL) $= Ls \times \frac{0,02}{0,02 \times e} = 17 \times \frac{0,02}{0,02 \times 0,085} = 3,23$ m

Run off Length (RfL) = Ls – Run off Length = 17 – 3,23 = 13.77 m

% Run off $= \frac{\left(\frac{2 \times LS}{3}\right) - RoL}{RfL}$

$= \frac{\left(\frac{2 \times 17}{3}\right) - 3,23}{13,77} \times 100 = 100$ %

c. Spiral - Spiral (S – C - S)

Run out Length (RoL) $= Ls \times \frac{0,02}{0,02 \times e} = 17,91 \times \frac{0,02}{0,02 \times 0,085} = 3,40$ m

Run off Length (RfL) = Ls – RoL = 17,91 – 3,40 = 14,51 m

% Run off $= \frac{\left(\frac{2 \times LS}{3}\right) - RoL}{RfL}$

$= \frac{\left(\frac{2 \times 17}{3}\right) - 3,40}{14,51} \times 100 = 100$ %

2. Curved Point Calculation 10

Curve point 10 is in mountainous terrain with coordinates 167 º 10 9 '31 "and includes the local road function, so the planned speed is 20 km/h with a radius of at least 15 m and a max. 10% superelevation plan.:

V_R = 20 Km/hour

R_{min} = 15 m

R_R = 16 m (take planning)

e_{maks} = 10% = 0,1

$\Delta = \frac{167 + 9 + 31}{3} = 167,19^0$

the width of the road = 3 metre

a. Distribution of the e-f method

$V = V_R \times 0,9 = 20 \times 0,9 = 18\ Km/hour$

$fmax = 0,192 - (0,00065 \times 20) = 0,179$

$Dmax = \frac{181914,038 \times (e_{max} + f_{max})}{V_R{}^2} = \frac{181914,038 \times (0,1 + 0,179)}{20^2} = 126,885$

$DPI = \frac{181914,038 \times (e_{max})}{V_R{}^2} = \frac{181914,038 \times (0,1)}{20^2} = 56,146$

$hPI = \frac{(e_{max}) \times V_R{}^2}{V^2} - e_{max} = \frac{0,1 \times 20^2}{18^2} - 0,1 = 0,023$

$S_1 = \frac{hPI}{DPI} = \frac{0,023}{56,146} = 0,00042$

$S_2 = \frac{fmax - hPI}{Dmax - DPI} - = \frac{0,179 - 0,023}{126,885 - 56,146} = 0,002$

Mo = $\frac{((DPI\ x(Dmax-DPI))x(S2-S1))}{2\ x\ DP1} = \frac{((56{,}146\ x(126{,}885-56{,}146))x(0{,}002-0{,}00042))}{2\ x\ 56{,}146} =$ 0,028

D = $\frac{1432{,}394}{R_{plan}} = \frac{1432{,}394}{16} = 89{,}52$

e+f = $\frac{D\ x\ V_R^2}{181914{,}038} = \frac{89{,}52\ x\ 20^2}{181914{,}038} = 0{,}197$

f = D < DPI

= $Mo\ x(\frac{D^2}{DPI})^2 + (DxS1)\ \ :\ Mo\ x\left(\frac{Dmax-D}{Dmax-DPI}\right)^2 + hPI + (S2\ x\ (D-DPI))$

=$0{,}028\ x(\frac{89{,}52^2}{56{,}146})^2 + (89{,}52x0{,}00042): 0{,}028\ x\left(\frac{126{,}885-89{,}52}{126{,}885-56{,}146}\right)^2 + 0{,}023 +$ $(0{,}002\ x\ (89{,}52-56{,}146))$

= 0,108 : 0,105 → **because D> DPI then the smallest is taken** → 0,105

e = $(e+f) - f = 0{,}197 - 0{,}105 = 0{,}092$

b. Design Transition Analysis

R_{min} = $\frac{VR^2}{127\ x\ (e+f)} = \frac{20^2}{127\ x\ (0{,}1+0{,}105)} = 15{,}36 \rightarrow 15{,}5\ metre$

(Control Radius = $R_{plan} > R_{min}$ =16 > 15,5 = OK !!!!

e_{design} = 0,092

Relative Slope = 50 m (comparison in **table 5)**

Ls (T = 3second) = $\frac{VR}{3{,}6}xT = \frac{20}{3{,}6}x3$ = 16,67

Ls (SHORTT formula) = $0{,}022\ x\ \frac{VR^3}{Rc\ x\ C} - 2{,}727x\frac{VR\ X\ e}{C}$

= $0{,}022x\frac{20^3}{0{,}4\ x16} - 2{,}727x\frac{20\ X\ 0{,}085}{0{,}4}$ = 14,952 m

$LS_{slope\ change}$ = $emax - 0{,}02\ x\frac{VR}{3{,}6x0{,}035}$

= $0{,}1 - 0{,}02\ x\frac{20}{3{,}6x0{,}035}$

= 12,698

LS_{design} = Ls (T=3 second) : LS SHORTT : $LS_{slope\ change}$

= 16,67 : 14,92: 12,69

= 16,67 (Take the biggest) →17 m (rounded off)

checking LS_{design} = $LS_{design} \leq 0{,}25$

= $\frac{LS^2}{24\ x\ Rplan} = \frac{17^2}{24\ x\ 16}$ = **0,753 ≤ 0,25** → Spiral required !!!

c. Full Circle

TC = $R_Rx(Tan\ ^1/_2\ \Delta)$

= 16 x (Tan ½ 167,19) = 142,53 m

EC = $T_Cx(Tan\ ^1/_4\ \Delta)$

= 142,53 x (Tan ¼ 167,19) = 127,43 m

LC = $\frac{\Delta\ x\ 2\ x\ \pi\ Rc}{360^0}$

= $\frac{167{,}19\ x\ 2\ x\ 3{,}14\ x\ 16}{360^0}$ =46,68 m

Chek LC = LC > Lcmin (VR = 20 km/hour = 40 m (**table 6)**)

= 46,68 > 40 m → **OK !!!!**

d. Spiral – Circle – Spiral (S-C-S)

Ls = 17 m

Ɵs = $\frac{LSx90}{\pi\ x\ Rr} = \frac{17\ x\ 90}{3{,}14\ x\ 16} = 30{,}43^0$

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ϴc	= Δ-(2 x ϴs) = 167,19 – (2 x 30,43^0) = 106,314^0
LC	= $\frac{\theta c\ x\ \pi\ Rc}{180^0}$
	= $\frac{106{,}31\ x\ 3{,}14\ x16}{180}$ = 29,68 m
Ltot	= Lc + (2 x Ls) = 29,68 + (2x17) = 63,68 m
P	= $\frac{LS^2}{6\ x\ Rr} - (Rr\ x\ (1-(\cos \emptyset s))$
	= $\frac{17^2}{6\ x\ 16} - (16\ x\ (1-(\cos 30{,}43))$ = 0,805 m
K	= Ls - $\frac{Ls^3}{40\ x\ Rr^2} - (Rr\ x \sin \emptyset s)$
	= 17 - $\frac{17^3}{40\ x\ 16^2} - (16\ x \sin 30{,}43)$ = 8,41 m
Es	= ((Rr + p) x (1/cos ½ Δ)) – Rr
	= ((16 + 0,805) x (1/cos ½ 167,19)) – 16 = 134,64 m
Ts	= ((Rr + p) x tan ½ Δ))) – k
	= ((19 + 0,805) x tan ½ 106,31))) – 8,41 = 158,122 m
Cek LC	= 0 > LC < 20
	= 0 > 29,68 < 20 → **OK (S – S)**

e. Spiral – Spiral

Ls min	= 17 m
ϴs	= $\frac{\Delta}{2} = \frac{167{,}19}{2}$ = 83,59^0
LS	= $\frac{\theta S\ x\ \pi\ x\ Rr}{90} = \frac{27\ x\ 3{,}14\ x\ 19}{90}$ = 17,91 m
Ltotal	= 2 x Ls min = 2 x 17 = 34 m
p	= $\frac{LSmin^2}{6\ x\ Rr} - (Rr\ x\ (1-(\cos \emptyset s))$
	= $\frac{17^2}{6\ x\ 16} - (16\ x\ (1-(\cos\ 83{,}59))$ = - 11,205 m
K	= Lsmin - $\frac{Lsmin^3}{40\ x\ Rr^2} - (Rr\ x \sin \emptyset s)$
	= 17 - $\frac{17^3}{40\ x\ 16^2} - (16\ x \sin 83{,}59)$ = 0,62 m
Es	= ((Rr + p) x (1/cos ½ Δ)) – Rr
	= ((16 + (-11,205)) x (1/cos ½ 167,19)) – 16 = 26,986 m
Ts	= ((Rr + p) x tan ½ Δ))) – k
	= ((16 + -(-11,205)) x tan ½ 167,19))) – 0,62 = 43,38 m

3. Superelevation diagram

a. Full Circle (FC)

Run out Length (RoL)	= Ls x $\frac{0{,}02}{0{,}02\ x\ e}$ = 17 x $\frac{0{,}02}{0{,}02\ x\ 0{,}092}$ = 3,03 m
Run off Length (RfL)	= Ls – Run off Length = 17 – 3,03 = 13.97 m
% Run off	= $\frac{\left(\frac{2\ x\ LS}{3}\right)-RoL}{RfL}$
	= $\frac{\left(\frac{2\ x\ 17}{3}\right)-3{,}03}{13{,}97}$ x 100 = 59,43 %

b. Spiral – Circle - Spiral (S – C - S)

Run out Length (RoL)	= Ls x $\frac{0{,}02}{0{,}02\ x\ e}$ = 17 x $\frac{0{,}02}{0{,}02\ x\ 0{,}092}$ = 3,03 m
Run off Length (RfL)	= Ls – Run off Length = 17 – 3,03 = 13.97 m
% Run off	= $\frac{\left(\frac{2\ x\ LS}{3}\right)-RoL}{RfL}$
	= $\frac{\left(\frac{2\ x\ 17}{3}\right)-3{,}03}{13{,}07}$ x 100 = 100 %

c. Spiral - Spiral (S – C - S)

Run out Length (RoL) = Ls x $\frac{0{,}02}{0{,}02\ x\ e}$ = 46,68 x $\frac{0{,}02}{0{,}02\ x\ 0{,}092}$ = 8,32 m

Run off Length (RfL) = Ls – RoL = 46,68 – 8,32 = 38,36 m

% Run off = $\frac{\left(\frac{2\ x\ LS}{3}\right)-RoL}{RfL}$

= $\frac{\left(\frac{2\ x\ 17}{3}\right)-8{,}32}{38{,}36}$ x 100 = 100 %

4. Calculation of Curved Points 11

Curve point 11 is in mountainous terrain with coordinates 43 º 34 34 '4 "and includes the local road function, then the planned speed is 20 km/hour with a radius of at least 15 meters and a max. 10% superelevation plan.:

V_R = 20 Km/hour

R_{min} = 15 m

R_R = 50 m (take Planning)

e_{maks} = 10% = 0,1

Δ = $\frac{43\ +\ 34\ +4}{3}$ = $43{,}57^0$

The width of the road = 3 m

a. Distribution of the e-f method

V = $V_R\ x\ 0{,}9\ = 20\ x\ 0{,}9 = 18\ Km/hours$

fmax = $0{,}192-(0{,}00065\ x\ 20) = 0{,}179$

Dmax = $\frac{181914{,}038\ x\ (e_{max}+\ f_{max})}{V_R{}^2} = \frac{181914{,}038\ x\ (0{,}1\ +\ 0{,}179)}{20^2} = 126{,}885$

DPI = $\frac{181914{,}038\ x\ (e_{max}\ )}{V_R{}^2} = \frac{181914{,}038\ x\ (0{,}1)}{20^2} = 56{,}146$

hPI = $\frac{(e_{max}\ )\ x\ V_R{}^2}{V^2} - e_{max} = \frac{0{,}1\ x\ 20^2}{18^2} -\ 0{,}1 = 0{,}023$

S_1 = $\frac{hPI}{DPI} = \frac{0{,}023}{56{,}146} = 0{,}00042$

S_2 = $\frac{fmax\ -hPI}{Dmax-DPI} -= \frac{0{,}179\ -0{,}023}{126{,}885-56{,}146} = 0{,}002$

Mo = $\frac{((\ DPI\ x(Dmax-DPI))x(S2-S1))}{2\ x\ DP1} = \frac{((\ 56{,}146\ x(126{,}885-56{,}146))x(0{,}002-0{,}00042))}{2\ x\ 56{,}146} = 0{,}028$

D = $\frac{1432{,}394}{R_{plan}} = \frac{1432{,}394}{50} = 28{,}64$

e+f = $\frac{D\ x\ V_R{}^2}{181914{,}038} = \frac{28{,}64\ x\ 20^2}{181914{,}038} = 0{,}063$

f = D < DPI

$= Mo\ x(\frac{D^2}{DPI})^2 +\ (DxS1)\ \ :\ Mo\ x\left(\frac{Dmax-D}{Dmax-DPI}\right)^2 +\ hPI + (S2\ x\ (D - DPI))$

$=0{,}028\ x(\frac{28{,}64^2}{56{,}146})^2 +\ (28{,}64x0{,}00042): 0{,}028\ x\left(\frac{126{,}885-28{,}64}{126{,}885-56{,}146}\right)^2 + 0{,}023 + (0{,}002\ x\ (28{,}64 - 56{,}146))$

= 0,019 : 0,017 → because D <DPI then the largest is Taken → 0,019

e = $(e+f) -\ f = 0{,}063 -\ 0{,}019 = 0{,}044$

b. Design Transition Analysis

R_{min} = $\frac{VR^2}{127\ x\ (emax+f)} = \frac{20^2}{127\ x\ (0{,}1+0{,}019)} = 26{,}46 \rightarrow 27\ metre$

(Chek Radius = $R_{plann} > R_{min}$ =50 > 27 = OK !!!!

e_{design} = 0,004

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Relative Slope = 50 m (comparison in table 5)

Ls (T = 3 second) $= \frac{VR}{3,6} xT = \frac{20}{3,6} x3 = 16,67$

Ls (SHORTT formula) $= 0,022\ x\ \frac{VR^3}{Rc\ x\ C} - 2,727x \frac{VR\ X\ e}{C}$

$= 0,022x \frac{20^3}{0,4\ x50} - 2,727x \frac{20\ X\ 0,044}{0,4} = 2,83$ m

$LS_{slope\ change}$ $= emax - 0,02\ x \frac{VR}{3,6x0,035}$

$= 0,1 - 0,02\ x \frac{20}{3,6x0,035}$

$= 12,698$

LS_{design} = Ls (T=3 second) : LS SHORTT : $LS_{slope\ change}$

= 16,67 : 2,83: 12,69

= 16,67 (Take the biggest) →17 m (rounded off)

Check LS_{design} = $LS_{design} \leq 0,25$

$= \frac{LS^2}{24\ x\ Rplan} = \frac{17^2}{24\ x\ 50}$ = **0,24 ≤ 0,25** → full circle !!!

c. Full Circle

TC $= R_R x(Tan\ ^1/_2\ \Delta)$

= 50 x (Tan ½ 43,57) = 19,98 m

EC $= T_C x(Tan\ ^1/_4\ \Delta)$

= 19,98 x (Tan ¼ 43,57) = 3,84 m

LC $= \frac{\Delta\ x\ 2\ x\ \pi\ Rc}{360^0}$

$= \frac{43,57\ x\ 2\ x\ 3,14\ \ x\ 50}{360^0} = 38,025$ m

Cek LC = LC > Lcmin (VR = 20 km/hours = 40 m (**table 6**))

= 38,025 < 40 m → **More Radius !!!!**

d. Spiral – Circle – Spiral (S-C-S)

Ls = 17 m

Θs $= \frac{LSx90}{\pi\ x\ Rr} = \frac{17\ x\ 90}{3,14\ x\ 50} = 21,78^0$

Θc = Δ-(2 x Θs) = 43,57 – (2 x $21,78^0$) = $24,093^0$

LC $= \frac{\theta c\ x\ \pi\ Rc}{180^0}$

$= \frac{24,093\ x\ 3,14\ x50}{180} = 21,02$ m

Ltot = Lc + (2 x Ls) = 21,78 + (2x17) = 55,02 m

P $= \frac{LS^2}{6\ x\ Rr} - (Rr\ x\ (1 - (\cos \emptyset s))$

$= \frac{17^2}{6\ x\ 50} - (50\ x\ (1 - (\cos 21,78)) = 0,243$ m

K $= Ls - \frac{Ls^3}{40\ x\ Rr^2} - (Rr\ x \sin \theta s)$

$= 17 - \frac{17^3}{40\ x\ 50^2} - (50\ x \sin 21,78) = 8,49$ m

Es = ((Rr + p) x (1/cos ½ Δ)) – Rr

= ((50 + 0,243) x (1/cos ½ 43,57)) – 50 = 4,107 m

Ts = ((Rr + p) x tan ½ Δ))) – k

= ((50 + 0,243) x tan ½ 43,57))) – 8,49 = 28,57 m

Cek LC = 0 > LC < 20

= 0 > 21,02 < 20 → **OK**

d. Spiral – Spiral

Ls min = 17 m

Өs $= \frac{\Delta}{2} = \frac{43,57}{2} = 21,78^0$

LS $= \frac{\theta S \; x \; \pi \; x \; Rr}{90} = \frac{21,78 \; x \; 3,14 \; x \; 50}{90} = 38,025$ m

Ltotal = 2 x Ls min = 2 x 17 = 34 m

p $= \frac{LSmin^2}{6 \; x \; Rr} - \; (Rr \; x \; (1 - (\cos \emptyset s))$

$= \frac{17^2}{6 \; x \; 50} - \; (50 \; x \; (1 - (\cos \; 21,78))$ = - 2,608 m

K = Lsmin - $\frac{Lsmin^3}{40 \; x \; Rr^2} - \; (Rr \; x \sin \emptyset s)$

= 17 - $\frac{17^3}{40 \; x \; 50^2} - \; (50 \; x \sin 21,78)$ = -1,607 m

Es = ((Rr + p) x (1/cos ½ Δ)) – Rr

= ((50 + (-2,608)) x (1/cos ½ 43,57)) – 50 = 1,037 m

Ts = ((Rr + p) x tan ½ Δ))) – k

= ((50 + -(-2,608)) x tan ½ 43,57))) – (-1,607) = 17,336 m

5. Superelevation diagram

a. Full Circle (FC)

Run out Length (RoL) = Ls x $\frac{0,02}{0,02 \; x \; e}$ = 17 x $\frac{0,02}{0,02 \; x \; 0,044}$ = 5,332 m

Run off Length (RfL) = Ls – Run off Length = 17 – 5,332 = 11.68 m

% Run off $= \frac{\left(\frac{2 \; x \; LS}{3}\right) - RoL}{RfL}$

$= \frac{\left(\frac{2 \; x \; 17}{3}\right) - 5,332}{11,68}$ x 100 = 51,43 %

b. Spiral – Circle - Spiral (S – C - S)

Run out Length (RoL) = Ls x $\frac{0,02}{0,02 \; x \; e}$ = 17 x $\frac{0,02}{0,02 \; x \; 0,044}$ = 5,332 m

Run off Length (RfL) = Ls – Run off Length = 17 – 5,332 = 11.68 m

% Run off $= \frac{\left(\frac{2 \; x \; LS}{3}\right) - RoL}{RfL}$

$= \frac{\left(\frac{2 \; x \; 17}{3}\right) - 5,332}{11,68}$ x 100 = 100 %

c. Spiral - Spiral (S - S)

Run out Length (RoL) = Ls x $\frac{0,02}{0,02 \; x \; e}$ = 38,025 x $\frac{0,02}{0,02 \; x \; 0,044}$ = 11,92 m

Run off Length (RfL) = Ls – RoL = 38,025 – 11,92 = 26,09 m

% Run off $= \frac{\left(\frac{2 \; x \; LS}{3}\right) - RoL}{RfL}$

$= \frac{\left(\frac{2 \; x \; 17}{3}\right) - 11,92}{26,09}$ x 100 = 100 %

The parameters of the re-planning results can be seen in Table 2.

Table 2. Redesign arch parameter

No. PI	9	10	11	Unit
STA	0+397.586	0+474.465	0+569.370	m
X	701.179,92	701.278,16	701.130,72	m
Y	9.187.450,05	9.187.628,01	9.187.462,76	m
Jarak	203,28	221,46	168,36	m
Speed	20	20	20	Km/hours
Delta	53° 58’ 52”	167° 9’ 31”	43° 34’ 4”	° ’ ”

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R	19	16	50	m
Ls	18	17	17	m
Teta S	27° 8' 24"	30° 26' 18"	9° 44' 25"	° ' "
Ts	19	158	29	m
Es	3,16	134,28	4,11	m
Lc	0,00	30	55	m
Lt	36	64	55	m
E Max	9	10	5	%

7. Vertical Alignment Calculation

At the location of the Sagaranten - Tegalbuled BDG 175 + 100 road, it has an uphill terrain accompanied by cliffs. STA 0 + 382 to 0 + 404 has slopes that are not under the provisions of Highways (max = 10%) with the slope calculation, namely:

$E_{beginning}$ = 414,57 $J_{beginning}$ = 382 m

E_{end} = 417,55 J_{end} = 404 m

Slope = $\frac{Eend-Ebeginning}{Jend-Jbeginning}x100\% = \frac{417,55-414,57}{404-382}x100\% = \frac{2,98}{22}x100\% = 13,59\ \%$

The slope determined by Bina Marga = Max. 10% ≤ 13,59% → **Not !!!!!**

Furthermore, at STA 0 + 404 to 0 + 550, the slope is not suitable, namely:

$E_{beginning}$ = 414,57 $J_{beginning}$ = 404 m

E_{end} = 436,46 J_{end} = 550 m

Slope = $\frac{Eend-Ebegin}{Jend-Jbegin}x100\% = \frac{436,46-414,57}{550-404}x100\% = \frac{21,89}{146}x100\% = 14,9\ \%$

The slope determined by Bina Marga = Max. 10% ≤ 14,9% → **Not !!!!!**

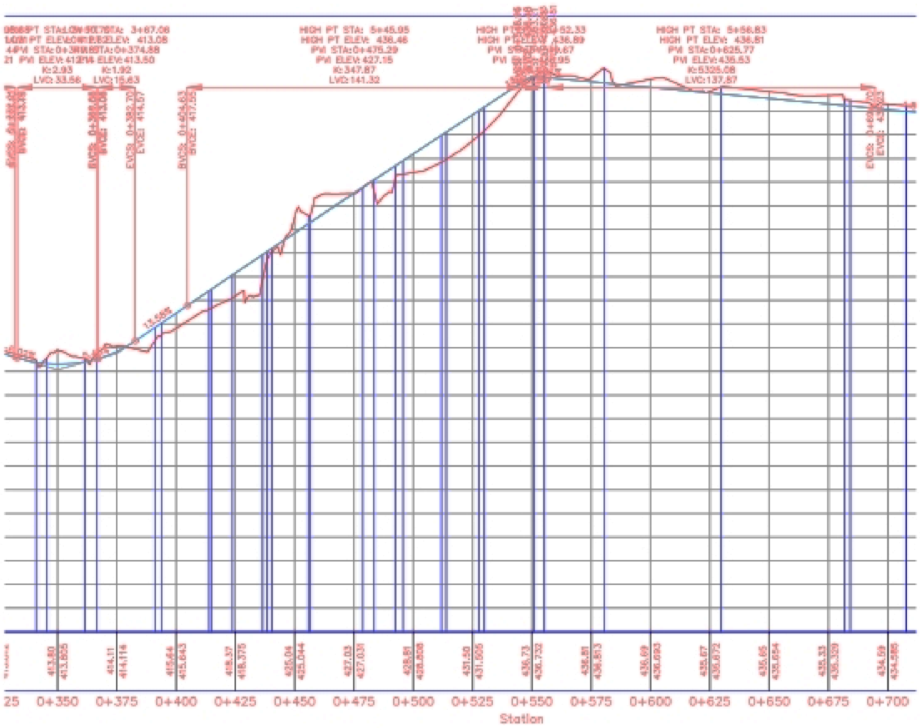

Figure 5. Depiction of the existing slope on Jalan Sagaranten - Tegalbuleud BDG 175+100 STA 0+350

With the condition of the existing slope that is not possible, a new road plan is made with a slope that has been adjusted to the Bina Marga Regulations.

a. STA Alignment Planning 0 + 350 - 0 + 399

E_{beginn} = 414,57 J_{beginn} = 404 m
E_{end} = 417,21 J_{end} = 550 m

Slope = $\frac{Eend-Ebegin}{Jend-Jbegin} x100\% = \frac{417,21-414,57}{350-399} x100\% = \frac{1,79}{49} x100\% = \mathbf{3,55}$ %

The slope determined by Bina Marga = Max. 10% ≥ 3,55% →**Secure !!!!!**

b. STA Alignment Planning 0 + 399 - 0 + 506

E_{beginn} = 417,08 J_{beginn} = 399 m
E_{end} = 425,89 J_{end} = 506 m

Slope = $\frac{Eend-Ebeginn}{Jend-Jbeginn} x100\% = \frac{425,89-417,08}{506-399} x100\% = \frac{8,81}{107} x100\% = \mathbf{8,2}$ %

The slope determined by Bina Marga = Max. 10% ≥ 8,2% → **Secure !!!!!**

c. STA Alignment Planning 0+506 – 0+536

E_{beginn} = 426,62 J_{beginn} = 536 m
E_{end} = 428,11 J_{end} = 563m

Slope = $\frac{Eend-Ebeginn}{Jbeginn-Jend} x100\% = \frac{428,11-426,62}{563-536} x100\% = \frac{1,49}{27} x100\% = \mathbf{5,5}$ %

The slope determined by Bina Marga = Max. 10% ≥ 5,5% →**Secure !!!!!**

d. STA Alignment Planning 0+536 – 0+638

E_{beginn} = 428,11 J_{bginn} = 536 m
E_{end} = 435,64 J_{end} = 638 m

Slope = $\frac{Eend-Ebeginn}{Jend-Jbeginn} x100\% = \frac{435,64-428,11}{638-536} x100\% = \frac{7,53}{75} x100\% = \mathbf{10}$ %

The slope determined by Bina Marga = Max. 10% ≥ 10 % →**Secure !!!!!**

e. STA Alignment Planning 0+638 – 0+661

E_{begin} = 435,60 J_{begin} = 638 m
E_{end} = 436,58 J_{end} = 661 m

Slope = $\frac{Eend-Ebeginn}{Jend-Jbeginn} x100\% = \frac{436,58-435,6}{661-638} x100\% = \frac{0,98}{23} x100\% = \mathbf{4,2}$ %

The slope determined by Bina Marga = Max. 10% ≥ 4,2% →**Secure !!!!!**

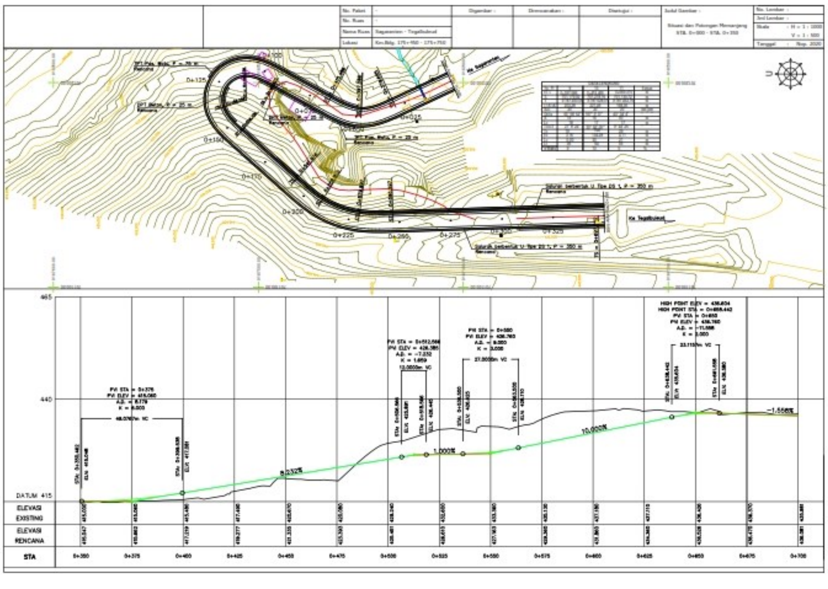

Figure 6. Describing the Slope of the Plan on Jl. Sagaranten - Tegalbuled BDG 175+100 STA 0+350

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CONCLUSION

This research has identified several curved radii on the existing road from 3 curves at curved points 9, 10, and 11 which have a curved radius of less than R_{min} = 15 m for VR = 20 km/hour due to hilly roads. The gradient values on the vertical alignment have 2 gradients that are more than e_{max} = 10%, which is equal to 13.59% and 14.9% which results in very steep inclines. The planning results show that there are three bends with the Spiral-Circle-Spiral type, namely bend 9 with a design curve of 17 m, bend 10 with a design curve of 17 m, and bend 11 with RC = 17 m. There are 5 slopes of vertical alignment consisting of: STA 0+350 – 0+399 of 3,55%, STA 0+399 s/d 0+506 of 8,2%, STA 0+506 s/d 0+536 of 5,5%, STA 0+536 – 0+638 of 10 %, STA 0+638 – 0+661 of 4,2%. The results of this study are suggested to be used for geometric road improvement on Jalan Sagaranten - Tegalbuled BDG 175 + 100 STA 0 + 350.

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