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Road Geometry Horizontal Alignment Planning Using Manual Design Method (Case Study Highway Kejayaan District – Pasrepan District, Pasuruan Regency, East Java STA 2+566 to STA 5+164)

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ABSTRACT

Pasuruan is a district in East Java Province, Indonesia. The capital city is Bangil District. Adequate transportation is one of the needs of the community. Along with the growing economic growth will also increase the volume of transportation in the region. Road transport safety is a global issue. Due to the large number of traffic accidents that occur, good road planning is needed, the geometric shape must be determined in such a way that the road in question can provide safety for road users in traffic. aims to carry out geometric planning of roads, especially horizontal alignment case studies of highways of Glory District – Pasrepan District STA 2+566 to.d. STA 5+164 Pasuruan Regency, East Java. In this study, it was concluded that the road is a primary collector road with a design speed of 80 km/hour, and a maximum slope (e) of 8%. With the road classification of the first and second Full Circle bends, as well as the third corner of the Spiral Circle Spiral. From the calculations, the horizontal arch length (Lc) at the first bend is 170.4095 m, at the second bend is 342.155 m, and at the third bend is 50.637 m.

1. Introduction

In Law Number 38 of 2004 concerning roads, it is stipulated that the meaning of a road is a land transportation infrastructure that includes all parts of the road including auxiliary buildings and equipment which is determined for traffic that is on the ground surface, below the ground surface and also on the water surface [1]. Roads are one of the infrastructure means of transportation whose role is crucial for the community. This important role mainly concerns the realization of balanced inter-regional development and the equitable distribution of development results in the framework of realizing national development.

Highways are the main roads that connect regions or regions with other regions or regions, especially for the continuity of the distribution of goods and services in the transportation sector. In the initial process, the geometric planning of the road must be carried out before the development is carried out so that road users feel comfortable. To get good and comfortable roads, according to the class of roads that have been determined by the government, namely the Directorate General of Highways, it is necessary to review the geometric aspects as a basis for planning to determine the speed of a feasible plan for the road [2].

Road accidents contribute the largest percentage in the form of losses and loss of life in accidents [3]. Accidents can be caused by several factors including vehicle eligibility, human negligence, environmental conditions, and also road geometry conditions [4]. The level of traffic accidents is strongly influenced by human factors, one of which is the speed factor. Vehicle speed is very influential

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in road accidents, especially in the corner area. The number of accidents on bends is more than accidents on straight roads, around 1.5 to 4 times [5]. The accidents with the highest number of injuries and deaths occur on the horizontal curves of the roads, this may be due to sudden changes in the characteristics of the road [6]. Mortality and damage from road accidents on corners is around 25%-30%. Sharp bends are locations that are very prone to accidents. The standard horizontal alignment geometry permits sharp turns only for roads with certain functions and low speeds [4].

Pasuruan is a district in East Java Province, Indonesia. The capital city is Bangil District. Adequate transportation is one of the needs of the community. People who do not have private means of transportation then switch to public transportation tools that rent out public transportation services by paying for each trip. The growing economic growth will also increase the transportation volume in the region. Road transportation safety is a global problem, in 2019 data released by the World Health Organization (WHO) recorded that 1.35 million people die yearly due to traffic accidents worldwide [7].

Due to the large number of traffic accidents that occur, good road planning is needed. The geometric shape must be determined so that the road in question can provide safety for road users in traffic. Writing this paper aims to carry out the geometric planning of the road, especially the horizontal alignment of the case study of the highways of the Glory District – Pasrepan District STA 2+566 to. STA 5+164 Pasuruan Regency, East Java. The hope is to create safe infrastructure, traffic flow efficiency, and maximize the ratio of usage levels.

2. Literature Review

2.1 Geometric Design

Roads are one of the land transportation accesses that connect one area to another. Road infrastructure services that are good, safe and smooth will be fulfilled if they meet the geometric technical requirements of the road [8]. Roads include all parts of the road, including auxiliary buildings and equipment intended for traffic, which are at ground level, above ground level, below ground level and or water, as well as above water level, except railroads, lorry roads and roads cable [9]. Road safety and comfort are factors that must be considered in planning road infrastructure [10]. The transportation network is a basic part of civil infrastructures and a crucial part of a sustainable development which plays a vital role in an efficient and reliable transportation system [11].

Geometric is part of road planning which is focused on planning physical form so that it can fulfill the function of the road. The purpose of road geometric planning is to produce safe infrastructure, service efficiency of traffic flow and maximize the ratio of usage/implementation costs [2] [12] [13] [14] [15] [16]. Road geometric planning is the beginning of a transportation network which the description of the physical form of the road to be built is incorporated into several road elements [17]. Road geometric planning aims to connect two or more locations appropriately, namely by considering the safety conditions of road users and the technical conditions of the area that will be traversed by road users [18]. In road planning, a method is needed to meet road service standards, namely a road width that is sufficient according to needs and bends based on the Highway Geometry Technical [19]. Road geometry planning must be adjusted to the needs, class of the road, and the type of vehicle that will pass so that vehicles with a certain design load and speed pass a road comfortably and safely [20].

2.2 Horizontal Alignment

The road is a ribbon of a three-dimensional entity, the space form of the road midline is called the route, and its projection line in the horizontal plane is known as the horizontal alignment of the road [21]. In the geometric planning of the road there are two alignments, consisting of a vertical alignment and a horizontal alignment. Horizontal alignment is an image that is made flush with the horizontal plane of

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the road [18]. Horizontal alignment is the horizontal shape of the road in a certain field, which can provide comfort, safety, or vice versa. Horizontal alignment can also be referred to as "road alignment" or "road situation", which is formed from straight lines connected by curved lines [22]. Horizontal alignment must be designed optimally as a provider of better connectivity between cities [23].
To design a horizontal line, the first thing that must be done is to determine the function and class of the road, which is based on the nature and volume of traffic that passes through the road and the terrain conditions [18].

2.3 Manual Road Design

Road quality planning can be done with proper construction planning, regular repairs and maintenance. Proper planning needs to be done to maintain the safety and comfort of road users [24]. An optimized road connecting specified points or sections on existing highways is desired for new highway construction [25] [26] [27] [28] [29]. An optimized road between tightly specified bounds may be desired in expansion projects. Determining the best option for new highway construction, realignment, or expansion falls in “Highway Route Optimization” or “Highway Alignment Optimization” [30].

Manual road design in outline/general to determine the road alignment after a decision has been made that the plan's location is feasible to build a road. In this initial planning, general research will be carried out on the selected planned route to determine or find possible local obstacles, which can be in the form of topographical conditions, such as hills, mountains, ravines, the groundwater table is close to the ground surface and land uses such as factories, the source of life for the local population. The geometric design is related to what is seen from the road, where safety is a major factor in the design of a road [31].

In addition to MKJI 1997 (Indonesian Highway Capacity Manual, 1997), SE PDGJ 2021 (Highway Design Standard of Indonesia 2021) is a more specific road geometric planning guideline. In various countries, it has its manual for designing roads, such as the USA using AASHTO (American Association of State Highway and Transportation Officials), Japan using JRA (Japan Road Association), Indians use IRC (Indian Road Congress), and others. Each guide has the same goal: to produce a product whose design is accurate, meets needs and technical rules, and can be applied in field implementation.

3. Method

3.1 Road Data

The location of the planned road is located on Jalan Raya Kejayan District - Pasrepan District, Pasuruan Regency, East Java STA 2+566 to. STA 5+164.

Figure 1. Location of Research

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This study uses a quantitative method, where the data obtained is processed mathematically based on formulas and rules with objective data used in 2021. The research data consists of map situations and coordinate data.

Improvement planning takes decisions to determine the direction of death with consideration of the following matters :

a. Connecting the broken road between Kejayan District and Pasrepan District in Pasuruan Regency.

b. This is the shortest and most effective distance compared to using other routes, based on the contours of the land.

c. Highways are used to increase the potential of the area and the surrounding area in the tourism and small and medium-sized economy.

4. Results And Discussion

4.1 Coordinate Point

Before calculating the horizontal alignment, obtaining the ground surface contour to calculate the coordinates of the connecting road to be built is necessary. As can be seen in Table 1, coordinate points on the horizontal alignment are obtained with the help of Global Mapper and implemented in AutoCAD® 2D.

Tabel 1 Horizontal Curvature Calculation

Point	Coordinate	
	X	Y
Start	12565253,9	859456,1
5	12565601,2	859924,7
6	12566191,2	860303,2
7	12566836,9	860492,5
End	12567471,4	860481,3

The coordinates were obtained from the results of data visualization from Google Earth to AutoCAD® 2D with the help of the Global Mapper application and 2 horizontal alignment curves were obtained which were made with the provisions of the first and second curves (Full Circle), and the third and fourth curves (Spiral-Circle-Spiral).

1) Coordinate deviation (Δx and Δy)

<u>Δx Coordinate x</u>

Δx start – 5 = 12565253,9 – 12565601,2 = 347,3
Δx 5 – 6 = 12565601,2 – 12566191,2 = 590,00
Δx 6 – 7 = 12566191,2 – 12566836,9 = 645,7
Δx 7 – end = 12566836,9 – 12567471,4 = 634,5

<u>Δy Coordinate y</u>

Δy start – 5 = 859456,1– 859924,7 = 468,6
Δy 5 – 6 = 859924,7 – 860303,2 = 378,5
Δy 6 – 7 = 860303,2 – 860492,5 = 189,2
Δy 7 – end = 860492,5 – 860481,3 = 11,1

2) Length Before the Curve (D)

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$$D = \sqrt{(\Delta x)^2 + (\Delta y)^2}$$
$$D(start - 5) = \sqrt{347{,}3^2 + 468{,}6^2} = 583{,}282\ m$$
$$D(5 - 6) = \sqrt{590{,}00^2 + 378{,}5^2} = 700{,}963\ m$$
$$D(6 - 7) = \sqrt{645{,}7^2 + 189{,}2^2} = 672{,}819\ m$$
$$D(7 - end) = \sqrt{634{,}5^2 + 11{,}1^2} = 634{,}622\ m$$

3) Azimuth Angle Calculation (Z)

$$Z = Arc\ tg\ \frac{\Delta x}{\Delta y} + 90$$
$$Z\ (start - 5) = Arc\ tg\ \frac{347{,}3}{468{,}6} + 90 = 143{,}455°$$
$$Z\ (5 - 6) = Arc\ tg\ \frac{590{,}00}{378{,}5} + 90 = 122{,}681°$$
$$Z\ (6 - 7) = Arc\ tg\ \frac{645{,}7}{189{,}2} + 90 = 106{,}336°$$
$$Z\ (7 - end) = Arc\ tg\ \frac{634{,}5}{11{,}1} + 90 = 88{,}995°$$

4) Delta Angle Calculation (Δ)

ΔAkhir (Seksi1) – Awal (Seksi2) = 143,455˚ – 143,455˚ = 0,000˚

ΔAkhir – 5 = 143,455˚ – 122,681˚ = 20,774˚

Δ5 – 6 = 122,681˚ – 106,336˚ = 16,345 ˚

Δ6 – 7 = 106,336˚ – 88,995 ˚ = 17,341˚

The resume results from calculating the coordinates to get azimuth angle, delta angle, and arc type determination.

Tabel 2 Horizontal Arch Planning Calculation

Point	Coordinates		Different Coordinates		Distance (m)	Azimuth (˚)	Δ (˚)	Curve Type
	X	Y	ΔX	ΔY				
Start	12565253,9	859456,1						
			347,3	468,6	583,282	143,455		
5	12565601,2	859924,7					0,000	**FC**
			590,0	378,5	700,963	122,681		
6	12566191,2	860303,2					20,774	**FC**
			645,7	189,2	672,819	106,336		
7	12566836,9	860492,5					16,345	**SCS**
			634,5	11,1	634,622	88,995		
End	12567471,4	860481,3					17,341	**SCS**

After obtaining coordinate data and curved length, proceed with data collection by calculating the horizontal curved curve according to PDGJ 2021.

A. Turn 1 (Full Cicle)

Δ = 20,774˚

Planned :

- Out of town road
- 4 lanes 2 directions divided

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- VR = 80 km/hour
- Rmin = 229.06 m
- R plan = 235.00 m

Calculation :

a. Define maximum super elevation (e_max)
The maximum super elevation provisions are 10%.

b. Determine the degree of curvature (D) and super elevation (e)

- $D = \frac{1432,4}{R\ rencana} = \frac{1432,4}{235,00} = 6,095\ m$
- $D = \frac{1432,4}{R\ min} = \frac{1432,4}{115229,06} = 6,253\ m$
- $e = \frac{e\ maks\ x\ D}{D\ maks} x \left(2 - \frac{D}{D\ maks}\right) = \frac{0,8\ x\ 6,095}{6,253} x \left(2 - \frac{6,095}{6,253}\right) = 10\%\ (0,080)$

c. Determine the transition curve (Ls)

- Δc = 0 maka Δ = 2 x θs
  20,774° = 2 x θs
  Θs = 10,387 °
- $Ls = \frac{\theta s\ x\ R}{28,648} = \frac{10,387°\ x\ 235,00}{28,648} = 85,205\ m$
- Lc = 0 maka L = 2 x Ls
  L = 2 x 85,205
  L = 170,4095 m
- $Xc = Ls - \frac{Ls^2}{6\ x\ R\ x\ Ls} = 85,205 - \frac{85,205^2}{6\ x\ 235\ x\ 85,205} = 84,925\ m$
- $Yc = \frac{Ls^2}{6\ x\ R\ x\ Ls} = \frac{85,205^2}{6\ x\ 235\ x\ 85,205} = 5,149\ m$
- P = Yc – R x (1 – cos θs)
  = 5,149 – 235 (1 – cos 34°)
  = 1,298 m
- K = Xc – R x sin θs
  = 84,925 – 235 x sin 10,387°

  = 42,555 m

- $Ts = (R + P) \tan\frac{\Delta}{2} + k$
  = (235 +1,298) x tan 20,774° + 42,555
  = 85,868 m
- $Es = \frac{(R+P)}{\cos\frac{\Delta}{2}} - R$

  $= \frac{(235+1,298)}{\cos\frac{20,774}{2}} - 235 = 5,235\ m$

B. Turn 2 (Full Circle)

Δ = 16,345°

Planned :

– Local road, secondary
– 4/2 D (4 lanes 2-way split)
– 2 x 2 x 3,5 m
– Vrencana = 80 km/hour

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- Rmin = 1100 m
- $e_{maks} = 0{,}08$

Calculation :

a. Determine the minimum radius (Rmin)
Adjusting to the design speed of 80 km/hour, minimum radius of 1100 m as described in table 3.

Table 3 Minimum Radius Without Bending

Speed Plan (Vr) (km/hour)	Minimum Radius (Rmin) (m)	Rmin without bend cross-falls
120	2000	3000
100	1500	2300
80	1100	1600
60	700	1000
40	300	420
30	180	240

b. Determine the degree of curvature (D) and Super Elevation (e)

- $f_{maks} = -0{,}000625\,V + 0{,}19 = (-0{,}000625\,x\,80) + 0{,}19 = 0{,}14$
- $R_{min} = \frac{v^2}{127}\,(e_{maks} + f_{maks}) = \frac{80^2}{127}\,(0{,}08 + 0{,}14) = 229{,}06\,m$
- $D = \frac{1432{,}4}{R_{rencana}} = \frac{1432{,}4}{1200} = 1{,}194$
- $Dmaks = \frac{1432{,}4}{R_{min}} = \frac{1432{,}4}{229{,}06} = 6{,}253$
- $e = \frac{emaks\,x\,D}{Dmaks}\left(2 - \frac{D}{Dmaks}\right) = \frac{0{,}08\,x\,1{,}194}{6{,}253}\left(2 - \frac{1{,}194}{6{,}253}\right) = 0{,}028 = 0{,}28\%$
- En = 0,02

c. Determining Fictitious Ls

- $B = \frac{1}{2}\,x\,lebar\,perkerasan = \frac{1}{2}\,x\,4\,x\,3{,}5 = 7\,m$
- $m = \frac{1}{landai\,relatif} = \frac{1}{1{:}200} = 200$

Diperoleh berdasarkan tabel 4.

Tabel 4 Landai Relatif Maksimum Antara Tepi Perkerasan

Speed Plan (km/jam)	60	80	100	120
Relative Slope	1 : 160	1 : 200	1 : 240	1 : 280

Ls fiktif = B x m (e + en) = 7 x 200(0,028 + 0,02) = 66,677 m

$$Ls\ luar\ lengkung = \frac{2}{3}\,x\,66{,}677\,m = 44{,}45\,m$$

$$Ls\ dalam\ lengkung = \frac{1}{3}\,x\,66{,}677\,m = 22{,}23\,m$$

d. Determine the start of the arc (TC), the distance PI to the arc (Ec), and the length of the arc (Lc)

- $TC = Rrenc\,x\left(tan\frac{\Delta}{2}\right) = 1200\,x\left(tan\frac{16{,}345°}{2}\right) = 172{,}335\,m$
- $Ec = \frac{R}{Cos\frac{\Delta}{2}} - R = \frac{1200}{Cos\frac{16{,}345°}{2}} - 1200 = 12{,}312\,m$
- $Lc = \frac{\Delta}{360}\,x\,2\pi R = \frac{16{,}345°}{360}\,x\,2.\pi.1200 = 342{,}155\,m$

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e. Determine the Pavement Width at the bend

The distance between the vehicle axles (P)	= 6.1 m
The distance between the axles to the front bumper (A)	= 1.2 m
Vehicle width (b)	= 2.4 m
Vehicle side clearance (c)	= 0.8 m
Number of lanes (n)	= 4 lanes

1. Offtracking Effect
   To compensate for offtracking, a single vehicle requires an additional width of:
   $b^n = Rrenc - \sqrt{Rrenc^2 - P^2} = 1200 - \sqrt{1200^2 - 6{,}1^2} = 0{,}0155\ m$
2. Friction Effect
   To compensate for the effect of shifting, from the results of field investigations it is necessary to increase the width:
   $Z = \frac{0{,}105\ x\ Vrenc}{\sqrt{R}} = \frac{0{,}105\ x\ 80}{\sqrt{1200}} = 0{,}242\ m$
3. The Distance to the front bumper effect
   Additional width as a result of the distance from the axle to the front bumper as follows:
   $Td = \sqrt{Rrenc^2 + A\ (2P + A)} - Rrenc = \sqrt{1200^2 + 1{,}2\ (2.6{,}1 + 1{,}2)} - 1200 = 0{,}0067\ m$

f. Pavement width at the bend
$B = n\ (b^n + b + c) + (n - 1)Td + Z$
$\quad = 4(0{,}0155 + 2{,}4 + 0{,}8) + (4 - 1)0{,}0067 + 0{,}242 = 13{,}125m$

B = 13,125 m < (2x2x3,5) m

g. Determines side clearance in corners
Vrencana = 80 km/hour and there is a road median, it is not possible to take turns at corners and JPH = 115 m and JPM = 520 m which are obtained from table 5 below:

Table 5. Stop and Standby Viewing Distances

Speed Plan (km/jam)	Stoppage Visibility (m)	Prepare Visibility (m)
30	30	80
40	40	140
50	55	200
60	75	380
80	115	520
100	165	670
120	225	790

S < L
115m < 342,115 m
L = 342,115m
$\Theta = \frac{90\ x\ S}{\pi\ x\ R} = \frac{90\ x\ 115}{3{,}14\ x\ 1200} = 2{,}747°$
Then, the side clearance area at the bend is:
m = R (1 – cos θ) = 1200 (1 – cos 2,747) = 1,379 m

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C. Turn 3 (Spiral Circle Spiral)

$\Delta = 17{,}341^{\circ}$

Planned :

- Local road, primary collector
- 4/2 D (4 lanes 2-way split)
- 2 x 2 x 3,5 m
- Vrencana = 80 km/hour
- Rrencana = 400 m
- $e_{maks} = 0{,}08$
- $e_n = 0{,}02$

Calculation :

a. Determine the minimum radius (Rmin)

$$f_{maks} = -0{,}000625\ x\ V + 0{,}19 = -0{,}000625\ x\ 80 + 0{,}19 = 0{,}14$$

$$R_{min} = \frac{V^2}{127}(e_{maks} + f_{maks}) = \frac{80^2}{127}(0{,}08 + 0{,}14) = 229{,}06$$

Rrencana = 400 m

b. Determine the degree of curvature (D) and super elevation (e)

$$D = \frac{1432{,}4}{Rrencana} = \frac{1432{,}4}{400} = 3{,}581°$$

$$Dmaks = \frac{1432{,}4}{Rmin} = \frac{1432{,}4}{229{,}06} = 6{,}253°$$

$$e = \frac{e_{maks}\ x\ D}{D_{maks}}\left(2 - \frac{D}{D_{maks}}\right) = \frac{0{,}08\ x\ 3{,}581}{6{,}253}\left(2 - \frac{3{,}581}{6{,}253}\right) = 0{,}065 = 0{,}65\%$$

c. Determine Ls

- Based on Relative Slope

$$B = \frac{1}{2}\ x\ lebar\ perkerasan = \frac{1}{2}\ x\ 2\ x\ 2\ x\ 3{,}5 = 7\ m$$

$$m = \frac{1}{landai\ relatif} = \frac{1}{1:200} = 200$$

Obtained based on table 6 below:

Table 6 Maximum Relative Slope Between Pavement Edges

Speed Plan (km/jam)	60	80	100	120
Relative Slope	1 : 160	1 : 200	1 : 240	1 : 280

1) $Ls\min = 0{,}022\ \frac{V^3}{R\ x\ C} = 0{,}022\ \frac{80^3}{400\ x\ 0{,}4} = 70{,}400\ m$ (the largest is selected)

2) $Ls\min = 0{,}022\ \frac{V^3}{R\ x\ C} - 0{,}727\ x\ 80\ x\ \frac{e}{C} = 0{,}022\ \frac{80^3}{400\ x\ 0{,}4} - 0{,}727\ x\ 80\ \frac{0{,}065}{0{,}4} = 34{,}746\ m$

3) $Ls\min = \frac{(e_{maks} - en)\ x\ V}{3{,}6\ x\ re} = \frac{(0{,}008 - 0{,}002)\ x\ 80}{3{,}6\ x\ 0{,}035} = 38{,}095\ m$

4) $Ls\min = \frac{V\ x\ t}{3{,}6} = \frac{80\ x\ 3}{3{,}6} = 66{,}67\ m$

- Determine θs (θs > 3)

$$\theta s1 = 28{,}648\ x\ \frac{Ls1}{R} = 28{,}648\ x\ \frac{70{,}4}{400} = 5{,}042°$$

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$$\theta s2 = 28{,}648\, x \frac{Ls2}{R} = 28{,}648\, x \frac{34{,}736}{400} = 2{,}488°$$
$$\theta s3 = 28{,}648\, x \frac{Ls3}{R} = 28{,}648\, x \frac{38{,}095}{400} = 2{,}728°$$
$$\theta s4 = 28{,}648\, x \frac{Ls4}{R} = 28{,}648\, x \frac{66{,}67}{400} = 4{,}775°$$

- Based on travel time

$$Ls = \frac{Vrenc}{3{,}6}\, x\, T = \frac{80}{3{,}6}\, x\, 3 = 66{,}667\, m$$

The largest Ls is taken, namely 66.667 m ≈ 67.00 m (based on relative slope)

d. Check LC (LC > 25)
ϴc1= 7,257 → Lc = 50,637 (TRUE)
ϴc2 = 12,365 → Lc = 86,283 (TRUE)
ϴc3= 11,884 → Lc = 82,926 (TRUE)
ϴc4 = 7,792 → Lc = 54,369 (TRUE)

e. Determine Lc

$$Lc = \frac{\Delta c}{360}\, x\, 2\pi\, x\, Rrenc = \frac{7{,}257°}{360}\, x\, 2\, x\, 3{,}14\, x\, 400 = 50{,}637\, m$$

f. Determine Arch Length (L)
L = Lc + 2LS = 50,637 + 2 (70,4) = 191,437 m

- Determine Xc

$$Xc = Ls - \frac{Ls^5}{40\, x\, Rrenc^2\, x\, Ls^2} = 70{,}4 - \frac{70{,}4^5}{40\, x\, 400^2\, x\, 70{,}4^2} = 70{,}345\, m$$

- Determine Yc

$$Yc = \frac{Ls^3}{6\, x\, Rrenc\, x\, Ls} = \frac{70{,}4^3}{40\, x\, 400\, x\, 70{,}4} = 2{,}065\, m$$

- Determine P
P = Yc – Rrenc (1 – cosθs) = 2,065 – 400 (1 – cos 5,042°) = 0,517m
- Determine k
k = Xc – Rrenc x sin θs = 70,345 – 400 (sin 5,042°) = 35,191 m
- Determine Ts

$$Ts = (Rrenc + P)\tan\frac{\Delta}{2} + k = (400 + 0{,}517)\tan\frac{17{,}341°}{2} + 35{,}191 = 96{,}267\, m$$

- Determine Es

$$Es = \frac{Rrenc + P}{Cos\frac{\Delta}{2}} - Rrenc = \frac{400 + 0{,}517}{Cos\frac{17{,}341}{2}} - 400 = 5{,}147\, m$$

g. Determine the width of the pavement at the bend
The distance between the vehicle axles (P) = 6.1 m
The distance between the axles to the front bumper (A) = 1.2 m

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Vehicle width (b) = 2.4 m
Vehicle side clearance (c) = 0.8 m
Number of lanes (n) = 4 lanes

- Offtracking Effect

$$b^n = Rrenc - \sqrt{Rrenc^2 - P^2} = 400 - \sqrt{400^2 - 6{,}1^2} = 0{,}0465\ m$$

- Friction Effect

$$Z = \frac{0{,}105\ x\ Vrenc}{\sqrt{R}} = \frac{0{,}105\ x\ 80}{\sqrt{400}} = 0{,}420\ m$$

- The Distance to the front bumper effect

$$Td = \sqrt{Rrenc^2 + A(2P + A)} - Rrenc = \sqrt{400^2 + 1{,}2\ (2\ x\ 6{,}1 + 1{,}2)} - 400 = 0{,}02\ m$$

h. Pavement width at bend

$$B = n\ (b^n + b + c) + (n-1)Td + Z$$

$$= 4\ (0{,}0465 + 2{,}4 + 0{,}8) + (4-1)\ 0{,}02 + 0{,}420 = 13{,}466\ m$$

B = 13,466 m < (2 x 2 x 3,5) m **Then the bend does not need to be widened**

i. Determine side clearance in corners

Vrencana = 80 km/hour and there is a road median, it is not possible to take turns at the JPH = 115 m and JPM = 520 m corners which are obtained from table 7 below:

Table 7 Stop and Standby Viewing Distances

Speed Plan (km/jam)	Stoppage Visibility (m)	Prepare Visibility (m)
30	30	80
40	40	140
50	55	200
60	75	380
80	115	520
100	165	670
120	225	790

S < L

115 < 191,437 m

$$\theta = \frac{90\ x\ S}{\pi\ x\ R} = \frac{90\ x\ 115}{3{,}14\ x\ 400} = 8{,}240°$$

Then, the lateral clearance area at the bend is:

M = R (1 – cosθ) = 400 (1 – cos 8,240) = 4,130 m

Table 8 STA Calculation

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	Curved STA				
Section	STA		Distance	Total	Information
1	STA	0+000	0	0	Start point
	STA	0+483	483	483	Start point - TS SS
	STA	0+605	122	605	Ls SS 1
	STA	0+726	122	726	Ls SS 2
	STA	1+157	430	1157	SS End - TS SCS
	STA	1+237	80	1237	Ls SCS 1
	STA	1+310	73	1310	Ls SCS
	STA	1+391	80	1391	Ls SCS 2
	STA	1+748	357	1748	SCS End - TC FC
	STA	2+205	457	2205	LC FC
	STA	2+567	362	2567	FC End - Section 1 End
2	STA	3+065	497	3065	Start point - TS SS
	STA	3+150	85	3150	Ls SS 1
	STA	3+678	85	3235	Ls SS 2
	STA	3+235	443	3235	SS End - TC FC
	STA	4+020	342	4020	Lc FC
	STA	4+424	404	4424	FC End - TS SCS
	STA	4+495	70	4495	Ls SCS 1
	STA	4+545	51	4545	Lc SCS
	STA	4+616	70	4616	Ls SCS 2
	STA	5+164	549	5164	SCS End - Section 2 End

5. Conclusion

From the results of the calculation of Jalan Raya Kejayaan District – Pasrepan District, Pasuruan Regency, East Java STA 2+566 to STA 5+164 it can be concluded that the road is a primary collector road with a design speed of 80 km/hour, and a maximum slope of (e) 8 %. With the road classification of the first and second Full Circle bends, as well as the third corner of the Spiral Circle Spiral. From the calculations, the horizontal arch length (Lc) at the first bend is 170.4095 m, at the second bend is 342.155 m, and at the third bend is 50.637 m.

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