Department of Digital Business
Journal of Artificial Intelligence and Digital Business (RIGGS)
Homepage: https://journal.ilmudata.co.id/index.php/RIGGS
Vol. 4 No. 4 (2026) pp: 8737-8747
P-ISSN: 2963-9298, e-ISSN: 2963-914X

Geometric Analysis of the Wantilan – Cipeundeuy Road Segment

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Abstract

The development of rural areas into sub-district regions in Subang Regency necessitates improvements in transportation infrastructure to support community mobility and agricultural product distribution. One important road segment that requires development is the Wantilan – Cipeundeuy Sub-district. This study aims to analyze the conformity of road geometric design based on the Road Geometric Design Guidelines (PDGJ, 2021), determine pavement layer thickness according to the Pavement Design Manual (MDP, 2024), and estimate construction cost requirements. The methods employed include primary and secondary data collection, geometric analysis, pavement design analysis, and cost estimation. Field data indicate that the ± 2 km road segment contains three main horizontal curves with a design speed of 80 km/h and a superelevation value of 6%. The calculation results show a curve radius of 252 meters with deflection angles ranging from 3,69˚ to 5,54˚, which comply with thw requirements of PDGJ 2021. The subgrade soil has a California Bearing Ratio (CBR) value of 6,5%, classified as medium bearing capacity soil. The pavement structure design consists of an HRS-BC surface layer, a 200 mm Class A aggregate base course, and a 200 mm Class A aggregate subbase course. The design life of the road is set at 12 years with an average annual rainfall of 1,500 – 1,800 mm. Based on the analysis results, the proposed geometric conditions and pavement design meet technical standards and are feasible to improve road user comfort and safety. This study is expected to serve as a technical reference for road network development in Subang Regency.

Keywords*: Highway Design, Geometric Design, Flexible Pavement, PDGJ 2021, MDP 2024*

1. Introduction

The development of rural areas into sub-district regions in Subang Regency has led to an increasing demand for reliable and efficient land transportation systems. One of the strategic connecting routes that plays an important role in supporting socio-economic activities is the Wantilan-Cipeundeuy Road segment, which connects Wantilan Village with the administrative center of Cipeundeuy Sub-district. This road functions as a collector road that integrates movements from residential areas to economic and industrial activity centers, as well as serving as an important access route for agricultural product distribution [1], [2].

However, existing conditions along several road segments indicate non-compliance with road geometric design standards and a gradual deterioration of pavement structure [3], [4], [5]. The increase in traffic volume, particularly heavy vehicles, accelerates structural degredation, which may reduce driving comfort and road user safety [6], [7]. Therefore, a comprehensive technical study is required to evaluate geometric conformity, pavement capacity, and the feasibility of planning costs based on the latest guidelines, namely the Road Geometric Design Guidelines (PDGJ, 2021) and the Pavement Design Manual (MDP, 2024) [8], [9].

This study was conducted as part of the Road Infrastructure Design course, using an approach based on field data collection, geometric analysis, pavement design analysis, and cost estimation. Through these analyses, the study aims to obtain planning results that meet technical, functional, and economic aspects in order to support improvements in the quality of the road network in Subang Regency.

The road segment under study has a total length of approximately 2 kilometers and is calssified as a two-lane undivided road. The pavement width varies between 5 and 6 meters, and the alignment includes three horizontal curves [10], [11], [12], [13]. Under these existing conditions, a comprehensive evaluation of design parameters such as minimum curve radius, superelevation, shoulder width, and stopping sight distance is required. This evaluation is essential to ensure that the road design meets safety and user comfort standards. Considering the existing of the Wantilan – Cipeundeuy Road, which variations in pavement width, the presence of several curves, and the characteristics of a two-lane undivided road, road infrastructure planning must address not only geometric aspects but also pavement structural strength. Evaluation of geometric conformity – such as curve radius, superelevation, shoulder width, and stopping sight distance – is crucial to ensure road user safety and comfort. In addition, the determination of appropriate pavement layer thickness based on subgrade conditions and planned traffic loads is necessary to ensure adequate structural performance [14], [15]. Therefore, this study aims to analyze road geometric conformity based on PDGJ 2021 and to determine pavement layer thickness requirements in accordance with MDP 2024.

2. Research Methodology

2.1 Study Location

The Wantilan – Cipeundeuy Road in Subang Regency, West Java, connects Wantilan Village in the east with Cipeundeuy Sub-district in the west. The road passes through residential areas, agricultural land, and small commercial zones with flat to gently rolling topography, making it suitable for a Class III road. It functions as an interregional connector and as a distribution route for agricultural products. Traffic is dominated by motorcycles, passenger cars, and light commercial vehicles, while supporting facilities such as drainage systems and road shoulders still require improvement.

Table 1. Road Design Criteria Standards

Road Function	Collector Road
Road Class	Clas III
Road Authority	Regency Road
Road Type	Two-Lane Undivided (2/2 UD)
Design Speed	80 km/h
Maximum Superelevation, e (%)	6%
Lane Width (m)	3,25 m
Shoulder Width (m)	2 m
Stopping Sight Distance (m)	130 m
Passing Sight Distance (m)	250 m
Maximum Grade (%)	7%
Critical Length (m)	250 m
Minimum Curve Radius, Rmin (m)	252 m
Minimum Transition Curve Length, Ls min (m)	50 m

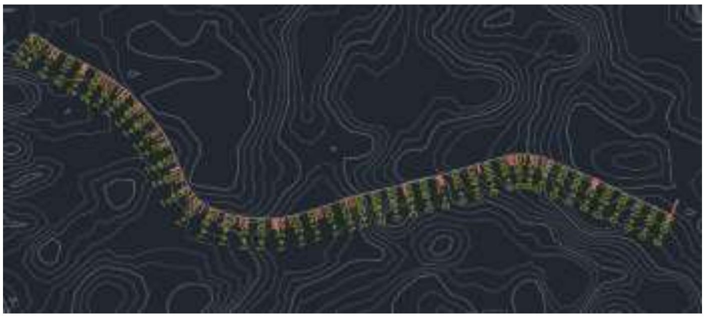

Fig 1. Cross Section

2.2 Data Collection Techniques

A. Primary Data

Primary data were obtained through a field survey conducted along approximately ± 2 km of the Wantilan – Cipeundeuy Road segment. The observations included [16], [17], [18]:

- Existing road conditions, including surface damage and unevenness
- Road geometric measurements at 50 m interval checkpoints
- Identification of curve points (Point of Intersection, PI)
- Longitudinal grades, pavement width, and surrounding environmental conditions

In addition, visual documentation in the form of photographs was collected to support the interpretation of field conditions.

B. Secondary Data

Secondary data were obtained from the 2025 traffic survey results, rainfall data for the Subang region, subgrade CBR data, and relevant design guideline references. The secondary data included:

- Average Daily Traffic (ADT) by vehicle classification
- Subgrade CBR value of 6,5%
- Annual rainfall ranging from 1.400 to 1.800 mm
- Pavement material parameters and design life

Secondary data served as the basis for pavement loading calculations, road classification, and geometric design analysis.

2.3 Data Analysis Techniques

After all data were collected, data processing and analysis were carried out as follows [19], [20], [21]:

A. Road Geometric Analysis

Geometric analysis was conducted to evaluate the conformity of existing road conditions with the PDGJ 2021 standards. The analysis stages included:

- Conversion of coordinates from DMS format to UTM coordinates
- Calculation of azimuth for each road segment
- Determination of deflection angles at each Point of Intersection (PI)
- Calculation of tangent length (T), curve length (L) and long chord length (LC)

The analysis applied a design speed of 80 km/h, a superelevation of 6%, and a lateral friction factor of 0,14. The results indicate that the road segment contains three horizontal curves categorized as gentle curves that meet the applicable design standards.

B. Pavement Analysis

Pavement analysis was performed using the MDP 2024 method based on the following parameters:

- Subgrade CBR value
- Pavement layer materials
- Equivalent standard axle load (ESA)
- Design life of 12 years

The analysis produced recommended thicknesses for the subbase course, base course, and surface layer in accordance with subgrade conditions and traffic loading [22], [23], [24].

2.4 Research Flowchart

The research activities were conducted following the workflow illustrated in Fig. 2. This study was carried out on the Wantilan – Cipeundeuy Road in Subang Regency, West Java Province, with the starting point at STA 0+000 and the ending point at STA 2+000.

DOI: https://doi.org/ 10.31004/riggs.v4i4.5098

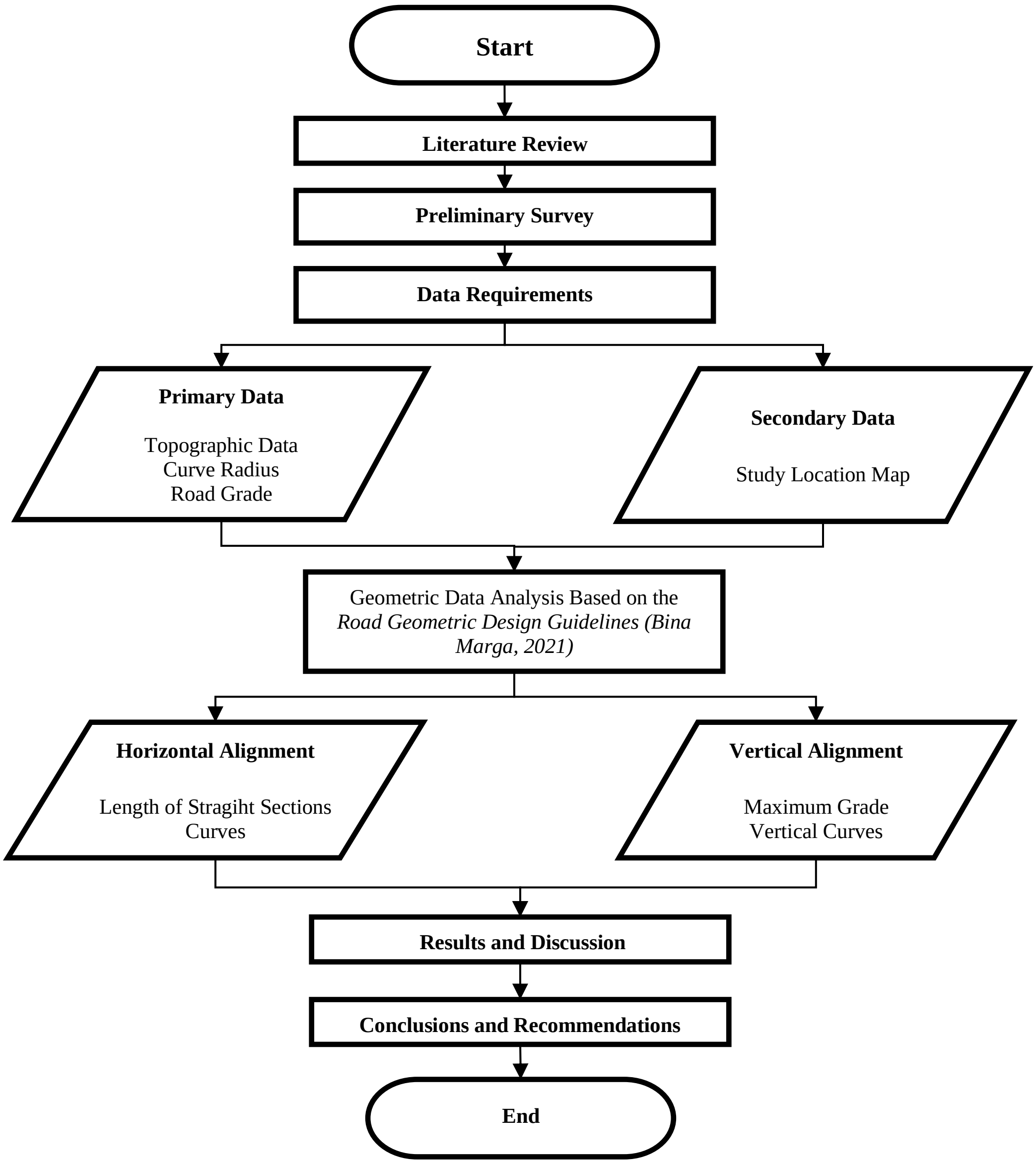

Fig 2. Flow Chart

3. Results and Discussion

3.1 Horizontal Alignment Analysis

The existing horizontal alignment analysis was conducted to determine the actual geometric conditions of the Wantilan – Cipeundeuy Road segment with a total length of 2 km. This analysis aims to describe the direction and shape of the road alignment by determining geometric parameters, including azimuth (α), deflection angle (Δ), tangent length (T), curve length (L), and long chord length (LC).

The coordinate data used were obtained from field surveys with observation intervals of every 50 meters, starting from STA 0+000 (Point A) to STA 2+000 (Point B). Based on field observations, the road segment contains three main horizontal curves located at STA -+250, STA 1+250, and STA 1+700. The analysis refers to the Road Geometric Design Guidelines (PDGJ, 2021) and the Pavement Design Manual (MDP, 2024). The design speed applied was 80 km/h with a superelevation value (e) of 0,06 and lateral friction factor (f) of 0,14.

3.1.1 General Road Segment Data

Based on the results of field measurements and coordinate mapping, thee Points of Intersection (PI) were identified, indicating the locations of horizontal curves, as presented in Table 2.

Table 2. Curve Locations

Curve Location	STA (m)	Description
Curve 1	0+250	First curve from the Wantilan direction
Curve 2	1+250	Second curve toward the Cipeundeuy direction
Curve 3	1+700	Final curve before Point B

3.1.2 Coordinate Conversion

Intial survey data were obtained in DMS (Degrees – Minutes – Seconds) format. To enable azimuth and distance calculations, the coordinates were converted into the UTM (Universal Transverse Mercator) coordinate system. The conversion formula from DMS to decimal degrees is expresseed as:

$$\text{Decimal Degrees} = \text{Degrees} + \frac{\text{Minutes}}{60} + \frac{\text{Seconds}}{3600}$$

Where:

- Degrees = principal value of the geographic coordinate
- Minutes = coordinate subdivision (1˚ = 60’)
- Seconds = smallest coordinate subdivision (1’ = 60’’)

3.1.3 Azimuth and Deflection Angle Analysis

Azimuth (α) is defined as the angle between the north direction and the line connecting two observation points. The deflection angle (Δ) represents the change in direction between two consecutive line segments.

$$\alpha = tan^{-1}\left(\frac{E_2 - E_1}{N_2 - N_1}\right)$$

$$\Delta = |\alpha_2 - \alpha_1|$$

Where:

- α = azimuth between segments (˚)
- Δ = deflection angle between two segments (˚)
- E_1, E_2 = Easting coordinates (m)
- N_1, N_2 = Northing coordinates (m)

3.1.4 Determination of Point of Intersection (PI)

The Point of Intersection (PI) is defined as the intersection point of two straight-line segments that form a change in direction. Based on the analysis results, three PI locations were identified, as presented in Table 3.

Table 3. Points of Intersection (PI) on the Wantilan - Cipeundeuy Road

Curve	STA (m)	Function	Description
1	0+250	PI1	Intersection of segments STA 0+200 – 0+300
2	1+250	PI2	Intersection of segments STA 1+200 – 1+300
3	1+700	PI3	Intersection of segments STA 1+650 – 1+750

3.1.5 Calculation of Horizontal Curve Parameters

The calculation of horizontal curve elements was carried out using the standard equations specified in PDGJ (2021) as follows:

$$R = \frac{V^2}{127(e + f)}$$

$$T = R \tan\left(\frac{\Delta}{2}\right)$$

DOI: https://doi.org/ 10.31004/riggs.v4i4.5098

$$L = \frac{\pi\, R\, \Delta}{180}$$

$$LC = 2\, R \sin\left(\frac{\Delta}{2}\right)$$

Where:

- R = curve radius (m)
- V = design speed (km/h)
- e = superelevation (decimal)
- f = lateral friction factor (decimal)
- Δ = deflection angle (˚)
- T = tangent length (m)
- L = curve length (m)
- LC = long chord (m)

3.2 Existing Vertical Alignment Analysis

Vertical alignment is a component of road geometric design that represents elevation changes along the road conterline. The objective of vertical alignment analysis is to describe ascending and descending road conditions, determine Points of Vertical Intersection (PVI), and design appropriate vertical curves to ensure that vehicles can travel safely and comfortably without abrupt changes in gradient (PDGJ, 2021).

Vertical alignment is classified into two types: crest curves, which occur when the road transitions from an upgrade. Both curve types are designed to provide smooth transitions between different grades while satisfying stopping with the design speed (Ministry of Public Works and Housing, 2021).

3.2.1 Basic Data

The data used in this analysis were obtained from field surveys conducted along the Wantilan – Cipeundeuy Road segments with a total length of 2 km an observation intervals of 50 meters.

The basic data are summarized as follows:

Road Name	: Wantilan–Cipeundeuy Road
Road Length	: 2,000 m
Observation Interval	: Every 50 m
Starting STA	: 0+000
Ending STA	: 2+000
Coordinate System	: UTM Zone 48S (WGS 84 Datum)
Data Type	: Elevation and geographic coordinate measurements
Design Speed (V)	: 80 km/h
Road Class	: Primary Collector
Topography	: Light hilly terrain
Reference Standards	: PDGJ (2021) and MDP (2024)
Analysis Objective	: Determination of grades, PVI locations, and existing vertical curve types

3.2.2 Grade Calculation Between Stations

Grade calculations were performed to determine elevation changes between stations along the existing road. The grade was calculated using the following equation:

$$g = \frac{(Z_2 - Z_1)}{(S_2 - S_1)} \times 100\%$$

Where:

g : grade between two points (%)
Z_1, Z_2 : elevations at the initial and final stations (m)

S_1, S_2 : horizontal distance between stations (m)

Table 4. Summary of Grades Between Stations

No	Initial STA	Final STA	Z1	Z2	ΔZ (m)	ΔS (m)	g (%)	Remarks
1	0+000	0+050	96961	95983	-0978	50	-1956	Downgrade
2	0+050	0+100	95983	97983	+1258	50	+2516	Upgrade
3	0+100	0+150	97241	98452	+1211	50	+2422	Upgrade
4	0+150	0+200	98452	101713	+3261	50	+6522	Upgrade
5	0+200	0+250	101713	102005	+0292	50	+0584	Upgrade
6	0+250	0+300	102005	101279	-0726	50	-1452	Downgrade
7	0+300	0+350	101279	99132	-2147	50	-4294	Downgrade
8	0+350	0+400	99132	97841	-1291	50	-2582	Downgrade
9	0+400	0+450	97841	96691	-1150	50	-2300	Downgrade
10	0+450	0+500	96691	96021	-0670	50	-1340	Downgrade
11	0+500	0+550	96021	95233	-0788	50	-1576	Downgrade
12	0+550	0+600	95233	94621	-0612	50	-1224	Downgrade
13	0+600	0+650	94621	94112	-0509	50	-1018	Downgrade
14	0+650	0+700	94112	93616	-0496	50	-0992	Downgrade
15	0+700	0+750	93616	92441	-1175	50	-2350	Downgrade
16	0+750	0+800	92441	91239	-1202	50	-2404	Downgrade
17	0+800	0+850	91239	89912	-1327	50	-2654	Downgrade
18	0+850	0+900	89912	88306	-1606	50	-3212	Downgrade
19	0+900	0+950	88306	86991	-1315	50	-2630	Downgrade
20	0+950	1.000	86991	85655	-1314	50	-2672	Downgrade
21	1.000	1+050	85655	83927	-1293	50	-3456	Downgrade
22	1+050	1+100	83927	82613	-1303	50	-2628	Downgrade
23	1+100	1+150	82613	81320	-1305	50	-2586	Downgrade
24	1+150	1+200	81320	80017	-1292	50	-2606	Downgrade
25	1+200	1+250	80017	78712	-1299	50	-2610	Downgrade
26	1+250	1+300	78712	77420	-1076	50	-2584	Downgrade
27	1+300	1+350	77420	76121	-0055	50	-2598	Downgrade
28	1+350	1+400	76121	75045	-0088	50	-2152	Downgrade
29	1+400	1+450	75045	74990	-0054	50	-0110	Flat
30	1+450	1+500	74990	74902	-0057	50	-0176	Flat
31	1+500	1+550	74902	74845	-0057	50	-0114	Flat
32	1+550	1+600	74845	74791	-0054	50	-0108	Flat
33	1+600	1+650	74791	74734	-0057	50	-0114	Flat
34	1+650	1+700	74734	74685	-0049	50	-0098	Flat
35	1+700	1+750	74685	74631	-0054	50	-0108	Flat
36	1+750	1+800	74631	74587	-0044	50	-0088	Flat
37	1+800	1+850	74587	74587	-0057	50	-0114	Flat
38	1+850	1+900	74530	74741	-0059	50	-0118	Flat
39	1+900	1+950	74741	74420	-0051	50	-0102	Flat
40	1+950	2.000	74420	74366	-0054	50	-0108	Flat

3.2.3 Determination of Point of Vertical Intersection (PVI)

The Point of Vertical Intersection (PVI) is the intersection point between two different grade lines in the vertical alignment. This point represents a change in the longitudinal slope direction, either from upgrade to downgrade or vice versa. PVI analysis was conducted to identify grade change locations and calculate vertical curve lengths to ensure safe and comfortable vehicle operation.

Table 5. Determination of Point of Vertical Intersection (PVI)

No	STA (PVI)	Elevation (m)	g1 (%)	g1 (%)	Grade Change	Curve Type
1	0+050	95,983	-1,956	+2,516	Form negative to positive	*Sag curve*
2	0+250	102,005	+0,584	-1,452	Form positive to negative	*Crest curve*
3	1+400	75,045	-2,152	-0,110	Decreasing downgrade	*Sag curve*
4	1+650	74,734	-0,114	-0,098	Nearly constant	Flat
5	1+950	74,420	-0,102	-0,108	Nearly constant	Flat

3.2.4 Summary of PVI Calculation Results

Table 6. Summary of PVI Calculation Results

STA (m)	Z (m)	g1 (%)	g1 (%)	Δg (%)	k	L (m)	Curve Type	STA PC	STA PT	Elevation PC (m)	Elevation PT (m)
0+050	95,983	-1,956	+2,516	4,472	30	134,16	Sag Curve	-0+017	-0+017	98,046	95,422
0+250	102,005	+0,584	-1,452	2,036	30	61,08	Crest Curve	0+219	0+219	101,671	102,027
1+400	75,045	-2,152	-0,110	2,042	30	61,26	Sag Curve	1+369	1+369	75,302	74,893
1+650	74,734	-0,114	-0,098	0,016	30	0,48	Flat	1+650	1+650	74,734	74,734
1+950	74,420	-0,102	-0,108	0,006	30	0,18	Flat	1+950	1+950	74,420	74,420

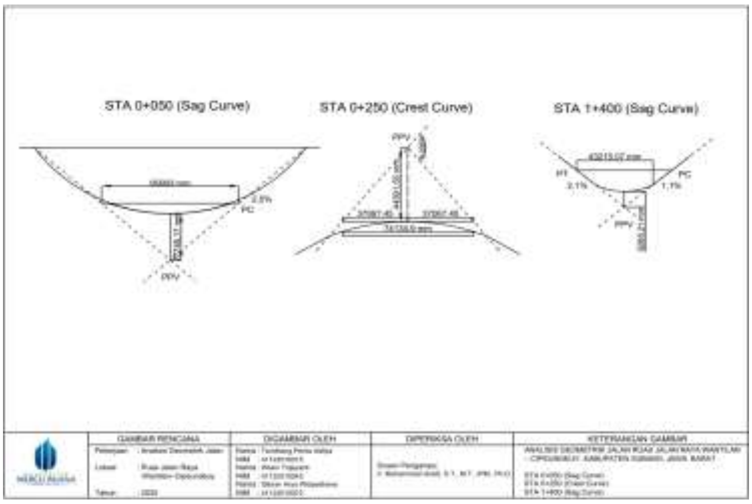

Fig 3. Vertical Alignment Sketch

3.3 Planned Vertical Alignment Analysis

Planned vertical alignment analysis was conducted to determine the design elevations at each station. The objective was to ensure that elevation changes between stations meet comfort, safety, and maximum grade criteria specified in PDGJ (2021). This analysis also identifies locations requiring cut and fill to ensure that the road surface follows the design profile.

Table 7. Summary of Planned Vertical Alignment

No	STA (m)	Curve Type	ZPV (m)	L (m)	STA PC	STA PT	Main Condition
1	0+050	Sag	95,983	134,16	-0+017,08	0+117,08	Minor fill → Major cut
2	0+250	Crest	102,005	61,08	0+219,46	0+280,54	Minor fill
3	1+400	Sag	75,045	61,26	1+369,37	1+430,63	Fill → Minor cut
4	1+650	Flat	74,734	0,48	1+649,76	1+650,24	Flat
5	1+950	Flat	74,420	0,18	1+949,91	1+950,09	Flat

DOI: https://doi.org/ 10.31004/riggs.v4i4.5098

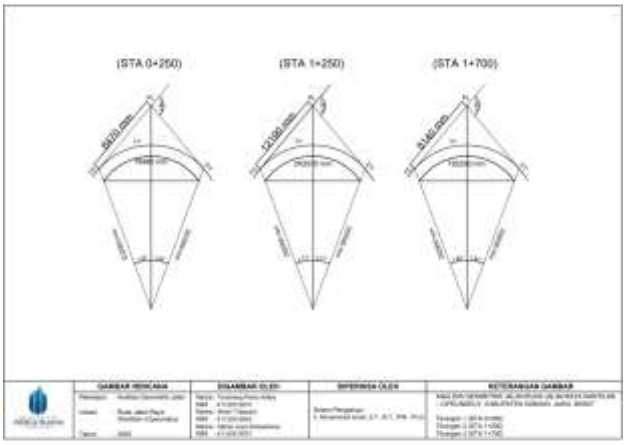

Fig 4. Horizontal Alignment Sketch

3.4 Road Drainage Planning Analysis

The road drainage system functions to safely and efficiently convey surface runoff away from the roadway to prevent ponding that could damage pavement structures. Drainage planning must consider hydrological factors, topographic conditions, and adequate channel capacity to accommodate maximum runoff discharge (Department of Public Works, 2020). In this study, the drainage system was designed to collect rainfall runoff from the road surface and surrounding catchment areas using the Rational Method to estimate design discharge and Manning's equation to determine channel and culvert dimensions.

3.4.1 Design Discharge Calculation Method

The maximum runoff discharge was calculated using the Rational Method, as the catchment area is relatively small (< 50 ha). The equation used is:

$$Q = C \times i \times A$$

Where:

Q = design discharge (m^3/s)

C = runoff coefficient

i = design rainfall intensity (m/s)

A = catchment area (m^2)

3.4.2 Design Data and Parameters

- Design rainfall intensity (i) = 100 mm/hour (based on assumptions for tropical regions; it will be adjusted using local rainfall data if available).

  $$i = \frac{100}{1000 \times 3600} = 2{,}78 \times 10^{-5} \ m/s$$
- Runoff coefficient (C) = 0.70 (combination of asphalt pavement area and unpaved road shoulders).
- Catchment area (A) = 1.0 ha = 10,000 m^2.
- Channel slope (S) = 0.01 (1%).
- Manning's roughness coefficient for pipes (n) = 0.013 (concrete pipe).
- Manning's roughness coefficient for earth channels (n) = 0.035.

Fig 5. Road Drainage Layout Sketch

4. Conclusion

Based on the results of geometric analysis and pavement structure planning for the ±2 km Wantilan–Cipeundeuy Road segment, it can be concluded that, in general, the existing road geometry complies with the requirements of the Road Geometric Design Guidelines (PDGJ, 2021). The road contains three main horizontal curves with a curve radius of 252 m, deflection angles ranging from 3.69° to 5.54°, and a superelevation of 6%, which are within acceptable limits for a design speed of 80 km/h. The vertical alignment analysis indicates that the existing grades are relatively mild to moderate, with several segments requiring vertical curve adjustments to ensure smooth grade transitions and to meet safety and comfort requirements. Based on pavement analysis using the Pavement Design Manual (MDP, 2024), with a subgrade CBR value of 6.5% and a design life of 12 years, the recommended flexible pavement structure consists of an HRS–BC surface layer, a 200 mm Class A aggregate base course, and a 200 mm Class A aggregate subbase course. This pavement structure is considered capable of supporting the planned traffic loads and is suitable for the existing subgrade conditions. Therefore, the proposed geometric and pavement designs are technically feasible and may serve as a reference for road development and quality improvement in Subang Regency, particularly in supporting road safety, comfort, and service performance.

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