THE GEOMETRIC DESIGN OF HORIZONTAL ALIGNMENT: A CASE OF BOJONGGEDE-KEMANG SECTION ROAD, WEST JAVA, INDONESIA

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ABSTRACT

Roads are one of the basic infrastructure facilities in the development of an area. With the construction of roads, they can be used as access to transportation and as a driving force for an area's economy to grow better. The purpose of geometric planning on the Bojonggede-Kemang section road at STA 0 + 000 - STA 1 + 200 is to obtain a design that prioritizes user safety and comfort. The method used in this study is a manual method that refers to the 2021 Road Geometric Design Guidelines (PDGJ). The data used in this study used Google Earth. The results of the study obtained a class III primary local type road. The plan speed of 60 km/h was obtained based on the criteria design. Then, using values, the horizontal alignment of the Bojonggede-Kemang road section is of type S-C-S.R = 150 m.

INTRODUCTION

Roads are one of the infrastructures needed by humans that are used to travel and for activities to deliver goods from one place to another. Road infrastructure plays an essential role by providing mobility for the efficient movement of people and goods and providing accessibility to various commercial and social activities. Transportation by road is the only mode to provide full service to everyone. As a result, roads have a more significant influence than other infrastructure in boosting economic growth (Ng, Law, Jakarni, & Kulantayan, 2019); (Nugraha, Prayitno, Situmorang, & Nasution, 2020).

Indonesia has abundant natural resources opening opportunities to become a developed country. Indonesia's national economy is expected to snowball after a decade of significant investment in public infrastructure projects emphasizing new roads, railways, ports, airports, power plants, distribution, water supply and sanitation, schools, and hospitals. Three main challenges of infrastructure development in Indonesia have been identified: land clearing, project planning and preparation, and financing. The uncertainty and scarcity of available funds for road infrastructure investment and competing priorities present challenges to the planning and execution of government infrastructure (Chan & Personal, 2022); (Salim & Negara, 2018); (Ben, 2019).

The Bojonggede-Kemang section road, located in Bogor Regency, West Java, is planned to be a link between Jalan Raya Parung in Kemang District and Jalan Tegar Beriman in

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Bojonggede District. Based on Bogor Regency Regional Regulation No.19/2008 concerning the Regional Spatial Plan of Bogor Regency, this area is included in the dense residential urban residential area (PP1). In the Third Part of the Regional Regulation (Regional Infrastructure System Development Plan) Paragraph 1 (Road Transportation System Development Plan), namely in article 57 paragraph (3), the new road development plan is carried out to connect regions and between residential centers, industry, agriculture, trade, services, and transportation nodes. Road infrastructure, as one of the transportation infrastructures, plays a role in encouraging economic growth because the availability of roads will minimize capital so that the production, distribution, and service processes will be more effective and efficient (Respitasari, 2021).

The new road development plan is a regency ring and a through road between border districts/cities, including the Rumpin – Ciseeng – Parung – Tajurhalang – Bojonggede – Cibinong (Tegar Imanman) – Citeureup section. With the construction of this connecting road, it is hoped that it can become an alternative road for road users from Kemang toward Bojonggede or vice versa. In the geometric planning of the road, the main factor that must be considered is the road user's safety. Therefore, one way to improve road safety is to improve the geometric design of roads to reduce the occurrence and severity of road accidents (Islam, Hua, Hamid, & Azarkerdar, 2019).

Geometric planning of this road aims to plan the road with safety aspects in mind. Most research involving safety road design components focuses on understanding the relationship between geometric, other design components, and safety, using accident records as an index and driver perception in various geometric and environmental conditions using simulations. Therefore, this planning is guided by the Road Geometric Design Guidelines (PDGJ) of 2021. The method used in this study is the manual method (Ukam & Emiri, 2019).

LITERATURE STUDY
Geometric Roads

Geometric Roads are a form of planning the shape of the road so that humans can transport from one area to another by prioritizing safety aspects. Geometric design plays a significant role in every street and weighs in the road's alignment. The design concept of a street must also pay attention to several aspects, such as; effective, efficient, economical, safe, and environmentally sound (Mandal, Pawade, & Sandel, 2019).

In determining the geometric design of a road, one must pay attention to several criteria. User safety is the main criterion in the geometric planning of a road. Geometric features can determine the shape of the driveway, such as curve radius, deflection angle, spiral length, tangent length, and road/lane/shoulder width, and any or all of these can be customized by the designer. These elements are elements in the geometric path used in planning (Pei, He, Ran, Kang, & Song, 2020).

The speed of the plan is also an essential element in road planning. The highest plan speed of the plan speed range is used so that the worst-case scenario possible on the road can be taken. The manual provides some minimum desired or absolute maximum values for some geometric
elements in each design speed. The type of road and the terrain are influential in determining the speed of the initial plan (Ukam & Emiri, 2019).

**Alignment Road**

Road Alignment is a projection of an arc on the geometric road. There are two types of alignment on the road: Horizontal Alignment and Vertical Alignment. Road alignment is a concern for designers and researchers worldwide because there are often accidents on the alignment of a road. Therefore, there is a need to measure, using the appropriate safety parameters in the elements of road design, the design's influence on road users' safety (Ukam & Emiri, 2019).

A vertical alignment, commonly referred to as a descent or climb, is an arc that is a projection of a line against an elevation or height in a collection of y-axis points. The height of these waypoints is usually determined by the need to provide the right level of driver safety, comfort, and drainage. In vertical alignment, there are two types of slump, namely positive (climb) and negative (derivative), and there are also two types of curvature, namely concave and convex arch (Mannering & Washburn, 2020).

Horizontal alignment or commonly referred to as bends or turns, is a curve that is a projection of a line against the points of the z and y axes. There are several types of horizontal alignment, namely Spiral-Circle-Spiral (S-C-S), Full Circle (F-C), and Spiral-Spiral (S-S). Spiral-Circle-Spiral (S-C-S) is the intersection of two lines connected by a combination of fixed radius curves (Circle) R combined with an intermediate form (Spiral). A full Circle (F-C) is one of the horizontal arches that connects two lines with the curvature of one circle. In comparison, the Spiral-Spiral (S-S) is one of the horizontal arches that connects two lines with two arch switches. Roads with this type of arch usually have a high design speed. In addition, poor visibility on the horizontal arch affects the increased risk of accidents due to lack of visibility (Papadimitriou, Eleonora, & al, 2019). It is fundamental research to optimize the road's horizontal alignments to improve the safety and economy of the designed horizontal alignment (You, Yu, Huang, & Hu, 2022).

**Road Classification**

Determining the classification of roads helps determine the type of road to be built to fit its function. In Indonesia, road grouping is explained in Law No. 38 of 2004 and Government Regulation No. 34 of 2006 concerning road designation, system, function, and status. By grouping a road, it is expected to follow the purpose for which a road is built. It is hoped that this grouping is also following the needs of a region to support activities and run the economic wheels of a region.

The construction of a road is also given some exceptions. Due to several factors, road construction can be carried out in stages. One of them is the limited funds owned by the government or private agencies authorized to build the road. The gradual development is expected to be born the development of the wheel of life of an area.
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Bojonggede-Kemang Section Road is planned as Primary Local Road. Primary local roads serve to connect the National Activity Center (PKN) with the Environmental Activity Center (PKL), the Wilaya Activity Center (PKW) with the Environmental Activity Center (PKLing), between (PKL) or (PKL) with (PKLing). With the characteristics of serving medium-distance traffic trips, medium average speed with Vd at least 20 km / h, a capacity more significant than the average traffic volume, a road width of at least 7.5 meters, the number of driveways is not limited (Road Geometric Design Guidelines, 2021).

Road Geometric Design Guidelines

Some countries have guidelines for the geometric design of a road. It is because each country has differences in various factors. Both from the habits of different drivers, vehicle standards, weather, and others. Traffic accidents involve human, vehicle, and environmental and road factors. It previously had its own standard for the geometric design of intercity roads in Indonesia, namely "Geometric Planning Procedures for Intercity Roads, No. 038/TBM/1997". The Directorate General of Wildlife Development created the standard in 1997. Currently, the latest road design standard is the Road Geometric Design Guidelines (PDGJ) 2021 (Elfandari, Amadea, & Siregar, 2021).

This PDGJ describes ways of geometrically designing roads which include design criteria, general provisions, road geometric technical provisions, and road geometric design procedures, in designing horizontal road paragraphs, vertical road paragraphs, road cross sections, and coordination of horizontal and vertical alignment of roads, for Highways, Medium Roads, Minor Roads, and Freeways, both serving Intercity traffic and inner-city traffic. This guide is mainly designed so that users can estimate the traffic behavior of a facility in specific traffic conditions, geometry, and environmental conditions (Isradi & Primary, 2020). Some parameters form the basis of geometric design: the vehicle's size, the plan's speed, the volume and capacity, and the level of service the road provides (Džambas, Ahac, & Dragčević, 2017).

METHOD

This study was in the Bojonggede-Kemang Section, Bojonggede District, Bogor Regency, West Java Province, Indonesia. The road was planned as a Primary Local road III. The plan to develop a new road functioning local primary III, a district ring, and a through road between border districts/cities includes the Rumpin – Ciseeng – Parung – Tajurhalang – Bojonggede – Cibinong (Tegar Imanman) – Citeureup section. Geographically, the location of the Bojonggede - Kemang road plan is located 2 km next to the embers of the Bogor Regency Government Office complex in Cibinong, which extends to cut the Parung Highway - Ciseeng Highway, with coordinates at 106°43’30" BT and 06°28'00" LS, administratively located in three sub-district areas, namely, Kemang District, Tajurhalang District, and Bojonggede District.
The systematic scientific research process must begin with identifying the right problem. Data is one of the main strengths in compiling scientific research and modeling. The primary data used in this study used data from Google Earth to find coordinates. In addition, there were secondary data on traffic volume carried out by the predecessor researcher and other parameters following the applicable rules (Rifai, Hadiwardoyo, Correia, & Pereira, 2016); (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015).

Geometric Planning of the Bojonggede-Kemang Road Section uses manual methods and procedures and design references using the 2021 Road Geometric Design Guidelines (PDGJ).

RESULTS AND DISCUSSION
The On-road planning based on the Indonesian Road Geometric Design Guidelines (PDGJI) 2021, here is the calculation of geometric road planning:

a. Determining the Main Design Criteria

On the Bojonggede-Kemang Road Section, it connects the IKK (Regency Capital) area in Bogor Regency, spreading to the IKC (District Capital) area in Parung District, passing

Figure 1. Location of research at Bojonggede-Kemang Route.
through the IKC (District Capital) Tajurhalang District, and ending at the IKC (District Capital) Bojonggede. This road is also linked to the National Road, namely Jalan Parung and Jalan Raya Bogor. Road grouping for Main Design Criteria as Public Roads, with Primary Local Road Function, Class III.

Table 1. Main Design Criteria Elements Table.

<table>
<thead>
<tr>
<th>No.</th>
<th>Main Design Criteria Elements</th>
<th>Main Design Criteria Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Road Role</td>
<td>Connecting between IKK and IKC</td>
</tr>
<tr>
<td>2.</td>
<td>Road Classification (Road Attribute)</td>
<td>Connecting between IKK and IKC</td>
</tr>
<tr>
<td></td>
<td>SJJ = Primary Status = County Roads</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Functions = Local Primary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class = III</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPPJ = JSD</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Design Speed Range (km/hour)</td>
<td>20-60 km/h</td>
</tr>
<tr>
<td>4.</td>
<td>Longitudinal Slope (G)</td>
<td>6%</td>
</tr>
<tr>
<td>5.</td>
<td>Superelevation (e)</td>
<td>8%</td>
</tr>
<tr>
<td>6.</td>
<td>Transverse Roughness ($f_{max}$)</td>
<td>0.17</td>
</tr>
<tr>
<td>7.</td>
<td>$R_{min}$ Horizontal Curve</td>
<td>114 m</td>
</tr>
</tbody>
</table>

The determination of Design Speed is a fundamental element in the road design used to select other geometric design parameters. Speed Design considers road users to be able to pass safely and comfortably at the specified speed limit in every possibility, such as all weather conditions, timing, traffic flow conditions, and interference from the driveway or others. Therefore, Design Speed is selected as the highest value from the allowed Design Speed range. Used Design Speed $V_D = 60 \text{ km/h}$.

b. Determining Technical Design Criteria

This technical design criterion refers to road technical data as well as all significant design criteria following the parameters of the latest regulation of the Director General of Highways, namely the Road Geometric Design Guidelines (PDGJ) 2021. For Design Clock Traffic Flow, data obtained through previous researchers is used. First, the Environmental Survey Team results in 2010, which received the average daily volume in the current year, rounded up. Then with a planned design life of 15 years and a traffic collision factor of 10%, the average annual daily traffic volume of the design was obtained. It is planned that the road will be very congested, then the K value for the design hour factor is 11%. Then it is obtained

$LHDRT_{TB} = 2802,625 \left(\frac{pcu}{hour}\right); LHDRT_{TB} = 3000 \left(\frac{pcu}{hour}\right); LHDRT_D = 3000 \times (1 + 10\%)^{15} = 12531,744 \left(\frac{pcu}{hour}\right) q_{JD} = 12531,744 \times 11\% = 1378,492 \rightarrow 1400 \left(\frac{pcu}{hour}\right)$
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Table 2. Table of Elements of Technical Design Criteria.

<table>
<thead>
<tr>
<th>No.</th>
<th>Elements of Technical Design Criteria</th>
<th>Technical Design Criteria Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Speed Design $V_D$, km/h</td>
<td>60</td>
</tr>
<tr>
<td>2.</td>
<td>Grade max, %</td>
<td>8</td>
</tr>
<tr>
<td>3.</td>
<td>Longitudinal Slope (G)</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td>Superelevation (e)</td>
<td>8</td>
</tr>
<tr>
<td>5.</td>
<td>Transverse Roughness ($f_{max}$)</td>
<td>0,17</td>
</tr>
<tr>
<td>6.</td>
<td>$R_{min}$ Horizontal Curve, m</td>
<td>114</td>
</tr>
<tr>
<td>7.</td>
<td>K Value Vertical Curve</td>
<td>K crest &gt; 11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K sag &gt; 38</td>
</tr>
<tr>
<td>8.</td>
<td>Type Road</td>
<td>2/2-TT</td>
</tr>
<tr>
<td>9.</td>
<td>Lane Width</td>
<td>5</td>
</tr>
<tr>
<td>10.</td>
<td>Outer roadside Width $L_{BL}$ on the new road, m</td>
<td>2</td>
</tr>
<tr>
<td>11.</td>
<td>Road lane slope, %</td>
<td>3</td>
</tr>
<tr>
<td>12.</td>
<td>Outer Roadside slope, %</td>
<td>6</td>
</tr>
<tr>
<td>13.</td>
<td>Road pavement type</td>
<td>Supple</td>
</tr>
<tr>
<td>14.</td>
<td>Road Space</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rumaja, m</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Rumija, m</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Ruwasja, m</td>
<td>7</td>
</tr>
</tbody>
</table>

c. Horizontal Alignment Calculation

Here are the coordinates of the road traffic on STA 0+000 and STA 1+200

Table 3. Road Trace Coordinate Table.

<table>
<thead>
<tr>
<th>Point</th>
<th>Coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
<tr>
<td>PI.1 STA 0+000</td>
<td>4992843,7436</td>
</tr>
<tr>
<td>PI.2 STA 0+600</td>
<td>4626446,6497</td>
</tr>
<tr>
<td>PI.3 STA 1+200</td>
<td>4161381,3588</td>
</tr>
</tbody>
</table>

1. The following is the calculation of horizontal alignment on PI.1:
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\[ R_{\text{min}} = \frac{v_D^2}{127 (f_{\text{max}} + e_{\text{max}})} \] ................................. (1)

\[ R_{\text{min}} = \frac{60^2}{127 (0.17 + 8\%)} = 113,386 \rightarrow \text{Direncanakan } R = 150 \text{ m} \]

\[ |X_2 - X_1| = 366397,0939 \]
\[ |X_3 - X_2| = 465065,2909 \]
\[ |Y_2 - Y_1| = 308447,6367 \]
\[ |Y_3 - Y_2| = 114459,8192 \]

2. Distance calculation.
\[ d_{1-2} = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2} \] ................................. (2)
\[ d_{1-2} = \sqrt{(366397,0939)^2 + (308447,6367)^2} \]
\[ d_{1-2} = 478,963 \text{ m} \]

3. Calculation of the azimuth angle.
\[ \alpha_{Pl,n} = \arctan \left( \frac{X_{n+1} - X_n}{Y_{n+1} - Y_n} \right) \] ................................. (3)
\[ \alpha_{Pl,1} = 49,908^\circ \]
\[ \alpha_{Pl,2} = 76,170^\circ \]

4. Calculation of the deflection angle.
\[ \Delta_{Pl,1} = |\alpha_{Pl,1} - \alpha_{Pl,2}| \] ................................. (4)
\[ \Delta_{Pl,1} = 49,908^\circ - 76,170^\circ = 26,270^\circ \]

5. Calculation of the length of the transitional arch: \( L_s \)
\[ L_s = \frac{v_D x T}{3,6} \] ................................. (5)
\[ L_s = \frac{60 x 3}{3,6} = 50 \text{ m} \]

6. Calculation Based on changes in centrifugal force and the influence of slope: \( L_s \)
\[ L_s = 0,022 x \frac{v_D^2}{RC x C} - 2,727 x \frac{v_D x e}{C} \] (6)
\[ L_s = 0,022 x \frac{60^3}{150 x 0,4} - 2,727 x \frac{60 x 8\%}{0,4} = 46,476 \text{ m } \rightarrow 47 \text{ m} \]

7. Calculation Based on maximum relative slump: \( L_s \)
\[ L_s = \left( \frac{e_m - e_n}{3,6 x r e} \right) x V_D \] ................................. (7)
\[ L_s = \left( \frac{8\% - 2\%}{3,6 x 0,025} \right) x 60 = 40 \text{ m} \]
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8. Calculation Based on driving comfort: $L_s$

\[
L_s = \frac{\sqrt{24 \times (P_{min}) x R}}{R} \nonumber
\]

\[
L_s = \frac{\sqrt{24 \times (0.2) x 150}}{150} = 26.833 \text{ m}
\]

9. The intermediate curved value is taken as the largest, then $L_s L_s = 50 \text{ m}$

Cheque $L_s$

\[
L_s \leq \frac{1}{2} x (6 \text{ seconds} \times V_p) \nonumber
\]

\[
L_s = 50 \text{ m} \leq \frac{1}{2} x \left(6 \times \left(\frac{60 \times 1000}{3600}\right)\right) = 50 \text{ m} \rightarrow \text{OK, planned 47 m}
\]

Used $L_s = 47 \text{ m}$

10. Run Out Calculation

\[
\text{Run Out} = \left(\sqrt{e_n} \times B \times M_{max}\right) \nonumber
\]

\[
\text{Run Out} = \left(0.02 \times 5 \times 167\right) = 16.7 \text{ m} \sim 17 \text{ m}
\]

11. Calculation $L_e$

\[
L_e = \text{Run Out} + L_s \nonumber
\]

\[
L_e = 17 + 47 = 64 \text{ m}
\]

12. Calculation of the shift value of the bend, if then the bend is of type S-C-S.$p \geq 0.25 \text{ m}$

\[
p = \frac{L_s^2}{24 \times R} \nonumber
\]

\[
p = \frac{47^2}{24 \times 150} = 0.614 \geq 0.25 \text{ m} \rightarrow \text{maka tikungan bertipe S – C – S}
\]


\[
\theta_s = \frac{90 \times L_s}{\pi \times R} \nonumber
\]

\[
\theta_s = \frac{90 \times 47}{\pi \times 150} = 8.976^\circ
\]

14. Calculation of the perpendicular distance from the TS point to the SC point.

\[
X_s = L_s - \frac{L_s^2}{40 \times R} \nonumber
\]

\[
X_s = 47 - \frac{47^3}{40 \times 150^2} = 46.885 \text{ m}
\]

15. Calculation of the perpendicular distance of the SC point on the arch.
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\[ Y_s = \frac{L_s^2}{6 \times RC} \] ..........................................................(15)
\[ Y_s = \frac{47^2}{6 \times 150} = 2,454 \text{ m} \]

16. Calculation of the distance of the TS point to the bend shift point.
\[ k = X_s - RC \times \sin \theta_s \] ..........................................................(16)
\[ k = 46,885 - 150 \times \sin(8,976^\circ) = 23,482 \text{ m} \]

17. Calculation of the tangent length from the point of PI to TS.
\[ T_s = (RC + p) \tan \frac{\Delta}{2} + k \] ..........................................................(17)
\[ T_s = (150 + 0.614) \tan \frac{26,270^\circ}{2} + 23,482 = 58,628 \text{ m} \]

18. Calculation of the distance from the PI point to the arc of the circle.
\[ E_s = (RC + p) \sec \frac{\Delta}{2} - RC \] ..........................................................(18)
\[ E_s = (150 + 0.614) \sec \frac{26,270^\circ}{2} - 150 = 4,661 \text{ m} \]

19. Calculation of the angle of the curved bend of the circle.
\[ \theta_c = (\Delta + 2\theta_s) \] ..........................................................(19)
\[ \theta_c = 26,270^\circ - 2(8,976) = 8,318^\circ \]

20. Calculation of the angle of the curved bend of the circle.
\[ L_c = \frac{2\pi}{360} \times \theta_c \times RC \] ..........................................................(20)
\[ L_c = \frac{2\pi}{360} \times 8,318^\circ \times 150 = 21,777 \text{ m} \]

21. Check \( L_c \)
\[ L_c \leq 6 \text{ detik} \times V_D \] ..........................................................(21)
\[ 21,777 \text{ m} \leq 6 \times \left( \frac{60 \times 100}{3600} \right) \]
\[ 21,777 \text{ m} \leq 100 \text{ m} \rightarrow \text{Complete} \]
\[ 21,777 \text{ m} > 20 \text{ m} \rightarrow \text{Complete} \]

The value of the super-elevation of roads in Indonesia both for outside cities and in cities varies, namely 2%, 4%, 6%, 8% and 10% (Procedures for geometric planning, Directorate General of Highways, 2021). However, according to Highways, the maximum e value for inner-city roads is 8% and 10% for out-of-town roads. Meanwhile, according to A Policy on Geometric Design of Highways and Streets, AASHTO, 2004 the maximum e value for all types of roads is 4%, 6%, 8%, 10% and 12%.
Analysis of road equipment is focused on identifying transportation facilities as road supports that are considered to have the potential to cause traffic accidents through a comprehensive, systematic, and independent road inspection concept. Analysis of the findings at the research location will be focused on findings that indicate a “No” answer as well as identification of other supports that are deemed not to meet the standards or technical requirements. Then make conclusions and suggestions from the inspection results in the study area.

CONCLUSION

The results of the planning research for the Bojonggede-Kemang Road showed that the Main Design Criteria Element obtained by the road was a Class III Primary Local type. Then the Technical Design Criteria Element produces a road type of 2/2 TT with a lane width of 5 m. With the speed of the plan and producing a geometric design, the horizontal alignment at STA 0 + 000 to STA 1 + 200 is a type of Spiral-Circle-Spiral (S-C-S). \( V_d = 60 \text{ km/jam} \) \( R_{design} = 150 \text{ m} \).

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