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Vertical Alignment Design of Special Operational Road: A Case TPA Bangkonol, Banten

[1]Dwiki Ali Sahara, [2]Andri Irfan Rifai, [3]Muhammad Alamsyah Irianto
[1]Faculty of Engineering, Universitas Mercu Buana, Indonesia
[2]Faculty of Civil Engineering & Planning, Universitas Internasional Batam, Indonesia
[3]Directorate General of Highway, Ministry of Public Works & Housing, Indonesia
E-correspondence: dwiki.ali.s@gmail.com

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Abstract
Infrastructure building is part of national development to provide services to the community. Road infrastructure development as an infrastructure for streamlined land transport. The problem with the current condition is that the operational road for access to waste disposal at the TPA Bangkonol is still in an unpaved road condition. The research mainly focuses on vertical alignment design. It is expected to get the results of efficient geometric design and meet the safety and comfort aspects. From the results of this study obtained vertical alignment calculation data, there are seven convex verticle curves and eight concave verticle curves on the operational road of TPA Bangkonol Pandeglang Regency. The technical design criteria for the design speed are 30km/hour. A maximum longitudinal grade value is 8% also a vertical Lmin is 18m. Geometric calculation of the TPA operational road based on the Highway Geometric Design Indonesia that can meet the safety and comfort aspects of drivers.

Keywords: Geometric design, Special operational Road, Vertical alignment,

1. Introduction

Infrastructure development is part of national development to provide services to the community. Development of road infrastructure as infrastructure for the smooth running of land transportation. Road infrastructure is the lifeblood of a region's economy; it connects and increases the movement of goods and people (Kusnadi & Natika, 2020). Steady quality of road infrastructure has been prioritized as the comfort and safety of road users.

Based on the Performance Report of the Pandeglang Regency Government Agencies for 2021, the Pandeglang Regency road infrastructure is still experiencing problems with road damage. Of the 723 kilometers of roads, 177 kilometers or else, around 24,61 percent are still in disrepair. The problem with the current condition is that the operational roads for access to waste disposal at the TPA still need to be recovered. Unpaved roads are usually constructed to serve particular areas and sometimes to improve accessibility to hard-to-reach areas (Shtayat, Moridpour, Best, Shroff, & Raol, 2020). Moreover, every time the rainy season comes, the subsidence of the soil surface causes the wheels of vehicles to get stuck, resulting in the accumulation of garbage at the entrance to the landfill. Based on these problems, it is necessary to carry out good road geometric design following technical road requirements to achieve safety and comfort for road users.

In vertical alignment design, environmental conditions and topography must be considered so that economical design can provide efficient services (Rees, 2021). The primary purpose of a road in providing vehicle circulation from a location to a destination location; it is significant to fully fulfill functional aspects, taking into account functionality, safety, economy, comfort, environmental integration, and harmony or aesthetics (Wilches, Burbano, & Sierra, 2020). Good design based on standards results in road construction that is safe against traffic during the design service life. Therefore, design standards are often used as a reference for designing road geometry. Indonesia's newest road geometric design standard is Highway Geometric Design Indonesia 2021.

Figure 1. TPA Bangkonol Operational Road Conditions

This research was conducted on the Operational Road of TPA Bangkonol, Pandeglang Regency (figure 1). The research is focused on vertical alignment design, so it is expected to get efficient geometric design results and meet safety and comfort aspects.

2. Literature Review

2.1. Road Geometric Design

Road geometric design includes a comprehensive technical design according to road alignment, road bodies including traffic lanes and road shoulders, drainage, bends, road grades, and earthworks for embankments and excavations. It is necessary to define the geometric road results so that the road's technical condition can optimize traffic flow according to its function (Ye, Wang, Liu, & Tarko, 2021). Road geometric design requires different parameters depending on the location and area to be implemented (Lopes, et al., 2019). There are three objectives in geometric road design, namely: providing driver comfort and safety in terms of visibility design, adequate road surface friction coefficient, and free space for maneuvering vehicles; guaranteeing an economical design; as well as obtaining uniformity of road geometry concerning the type of terrain.

The geometric design also needs to pay attention to the geometric aspects of the road for the safety, comfort, and safety of road users. In some cases, the road's geometric conditions affect the highway's accident rate (Álvarez, Fernández, Gordaliza, Mansilla, & Molinero, 2020). The result of proper geometric design can reduce accidents and their severity. Therefore, the geometric design aims to provide optimal traffic services and maximum safety at an economical price (Chakole & J.Wadhai, 2022).

Its designation divides public and particular roads (Direktorat Jenderal Bina Marga, 2021). Particular roads are not used for public traffic but for the benefit and direct benefits of individuals, certain community groups, business entities, or specific agencies. Based on the provisions, the operational road for TPA Bangkonol is classified as a particular road because its operation is only for access to certain agencies and regions. Furthermore, roads are grouped according to function, traffic intensity plays a role in road use management, and its smoothness is classified into four classes (Direktorat Jenderal Bina Marga, 2021).

Vertical alignment is a projection of a vertical plane with an intersection with the road's centerline. Changes from one slope to a different slope, the transition uses a vertical curve. The shape of the vertical alignment when designing the road geometry is made according to the subgrade surface. This subgrade will reduce soil work (balance between *cut* and *fill*) (Akhmet, Hare, & Lucet, 2022). In addition, for safety and comfort, it is crucial to avoid slopes that change suddenly with short distances and very long ascents/descents. For example, if you want to reduce the speed of a truck, you need to design a large descent ramp followed by an ascent lane (Qi, 2020).

Based on the point of intersection of the two straight parts (tangent), the type of vertical curve consists of a convex vertical curve where the intersection point between the two tangents is above the road surface. In contrast, a concave vertical curve is a curve where the point of intersection of the two tangents is below the road surface. Therefore, changes in the alignment of the vertical alignment can significantly affect the quality of the geometric design of the road (Zhang, Zhang, Zhang, & Hou, 2021).

The light irradiation distance is the visibility that can be seen at night. Visibility is one of the critical criteria for designing road geometrics to avoid accidents (Islam, Hua, Hamid, & Azarkerdar, 2019) . To avoid negative impacts on operation and traffic safety, the policy of establishing minimum visibility between the safety barrier and the carriageway compels designers to provide an adequate level of visibility for emergency braking (Lioi, Hazoor, Castro, & Bassani, 2022) . With a longer visibility distance, it can increase the additional time for the driver's reaction so that the risk of collision is reduced and road safety increases (Shirini & Kordani, 2019) . Usually, the height of the headlights is set at about 60 cm from the road, and the spread angle is 1 degree. Therefore, the position of the vehicle's headlight irradiation is divided into the visibility of the headlights < L and the visibility of the headlights > L.

The free sight distance under the building is the driver's line of sight when driving past other buildings, so the view is often blocked by the underside of the building (Kairupan, Manoppo, & Waani, 2022) . The minimum concave vertical arc length is determined based on the minimum stopping sight distance and the assumption that the driver's eye height is 180cm and the object height is 50cm (height of the taillights). Vertical clear space of at least 5 m is recommended to set at least 5.5 m to accommodate the need for road overlays in the future.

2.2. Geometric Design for Special Operational Road

TPA in Indonesia is still considered the main activity of landfilling, accumulating waste in an open-damping manner. It is not surprising that waste management has yet to be well planned so as not to disturb the surrounding environment (Ariyani, 2018) . Access roads for landfill operations must meet appropriate road standards with adequate width, slope, visibility, and construction to accommodate projected truck traffic. Access roads that have not been paved cause dirt to stick to truck tires, making it difficult for trucks to walk and contaminating the road that the dump truck is traversing (Vern, Razakamanantsoa, Murzyn, Larrarte, & Cerezo, 2022).

Some roads in Indonesia, especially regional roads, have rough road geometric conditions and were not planned before they were built, only following existing road conditions, so the geometric model of the road sections is irregular. (Elfandari & Siregar, 2021). Through designing a vertical alignment that complies with the provisions, it is hoped that the road geometry will be safe, smooth, and comfortable for the driver (Chaudhari, Goyani, Arkatkar, Joshi, & Easa, 2022) . Vertical alignment designing in the provisions of the Road Geometric Design Guidelines No.20/SE/Db/2021 (Dirjen Bina Marga KEMENPUPR) discusses 12 topics of discussion, including design control, groundwater level, vertical free space, underground utility networks, grading points, minimum long slope, critical slope length, hiking trails, rescue lanes for brake check areas, overtaking lanes and vertical curve shapes.

Then, the parameters that have been calculated need to be controlled for vertical alignment, which includes the slope line must be smooth and having a consistent gradual change of the road terrain should be sought rather than a short slope with lots of faults. Recessed basin-type profiles should be avoided (Papadimitriou, et al., 2019). Hidden depressions make it difficult for the driver to see the pavement. This is avoided using gradual gradients or horizontal curves, wavy longitudinal slopes, especially on long descents without going uphill first. Resulting in the truck speeding too much, which has the potential to cause an accident (Wang & Wang, 2018) ; Longitudinal slopes broken back or two vertical curves in one direction separated by a short road with a straight slope should be avoided.

If the length extends straight beyond 0.4Vd (where V = design speed), then the curve is not called a *broken back curve*. In addition, it requires a quite long elongated ramp, preferably in flattening the slope closer to the apex, but without increasing the base slope; at a level intersection, a slope extends along the road. The slope of the road is made flat at the intersection so that it helps vehicles to turn at the intersection; Concave arches should only be made in excavations if drainage is adequate.

3. Methodology

The systematic scientific research process must begin with identifying the right problem (Rifai A. I., Hadiwardoyo, Correia, & Pereira, 2016). Accurate road alignment and roadway models are influential in various transport research and practice, making them an increasingly important part of road surveying (Zhou, Huang, Jiang, Dong, & Yang, 2021). The research method must follow systematic and measurable stages. The quantitative method is used for the geometric design criteria for the TPA's operational road. Quantitative research methods originate from mathematical sample data in obtaining geometric road standards. The guideline for standard provisions used in this study follows the Road Geometric Design Guidelines No.20/SE/Db/2021. This standard was revised in the Procedures for Geometric Design for Highway Roads in 1997. Changes were made to keep up with road developments after the publication of Law of the Republic of Indonesia Number 38 of 2004 concerning Roads and their derivatives.

This research is located on the operational road section of the Bangkonol Final Waste Disposal Site, Pandeglang Regency. For more details, the research location is shown in Figure 2. The design of this operational road will be passed by garbage transport vehicles. In distribution activities, travel time is influenced by several factors, such as a vehicle, traffic, and road conditions (Susanti, Indrawati, Sitepu, Nabila, & Wulandari, 2020), so it is considered when the research is carried out on weekdays in waste transportation.

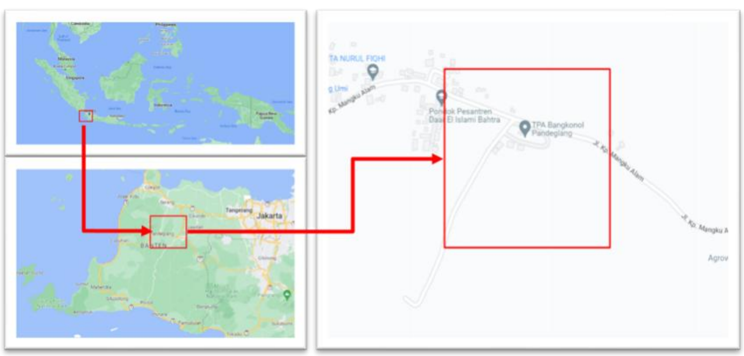

Figure 2. Research location

Data is one of the main strengths in compiling research and scientific modeling.. Primary data collection method, obtained directly in the field by measurement. The primary data obtained consisted of road condition elevation data and a situation map of the *existing conditions,* the research instruments used were GPS, tape measure, and writing instruments. Retrieval of secondary data from agencies dealing with public works in the Pandeglang Regency Government to obtain a contour map of the area. The designing method is based on the data obtained using the 2021 Highway Geometric Design - Indonesia.

4. Result and Discussion

From the GPS search results, the profile of the existing road length is obtained, as shown below. The following data is used as a layout in designing vertical alignment. From the drawing, it is necessary to design a vertical curve that meets the geometric design standards for a safe road. Different roads in urban areas are considered entirely on flat terrain, and roads in areas outside the city, including roads serving Intercity and freeway, can be in the three terrain classifications. On flat terrain, visibility is generally extended and can be made without construction difficulties or great expense. In hilly terrain, natural slopes that go up and down, and sometimes steep slopes limit the shape of the horizontal and vertical alignments to meet the technical requirements of road alignment. Finally, sudden longitudinal and transverse changes in the ground surface in mountainous terrain often cause alignment deviations and require excavation or backfilling to obtain horizontal and vertical alignments that meet the design criteria.

In general, mountain terrain results in steeper longitudinal road alignments compared to hilly terrain, and hill terrain results in steeper longitudinal gradients compared to flat terrain, causing heavy trucks to reduce their speeds which are generally much lower. Then the speed of a passenger car, mountain and hill terrain has a more significant effect than flat terrain in determining road alignment. Therefore, special road conditions require good attention in design to be safe.

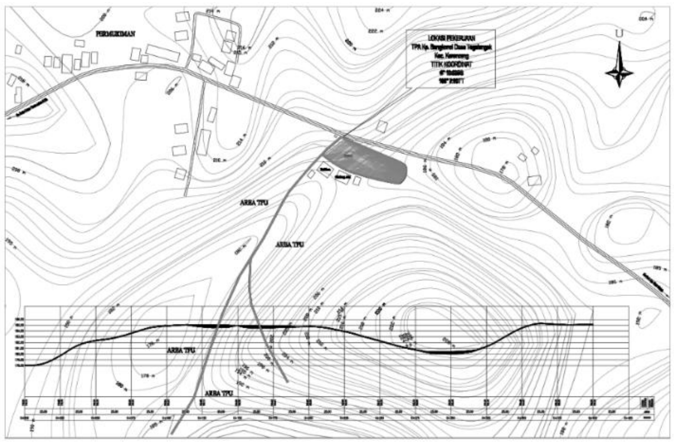

Figure 3. Profile the operational road

A vertical alignment is an elongated profile along the road's center line, formed from a series of segments with longitudinal slopes and vertical curves. The profile depends on topography, horizontal alignment planning, design criteria, geology, earthworks, and other economic aspects. To distinguish the topography, the terrain is divided into three categories: flat, hills, and mountains. On flat terrain, visibility is usually easier to meet without the difficulty of constructing it or not costing much. On hill terrain, the natural slope rises and falls consistently concerning the road. Sometimes, steep slopes limit typical horizontal and vertical alignment designs. In mountainous terrain, changes in ground surface elevation both longitudinally and transversely along road alignments occur suddenly, often resulting in the need for steep excavations and benching to obtain proper horizontal and vertical alignments.

4.1 Design Criteria

The operational road for TPA Bangkonol, Pandeglang Regency, connects a secondary area to the surrounding settlement persil according to the classification criteria as a unique road, the function of a secondary local road, class II road. Table 1 shows the main design criteria.

Table 1. Main Design Criteria

No.	Key Design Criteria Elements	Main Design Criteria Value
1.	Connecting Role	Point A to Point B as part of the role of connecting KS1 to Persil
2.	Road Classification *(Road Attribute)*	▪ Special Road ▪ SJJ: Secondary ▪ Status: Regency Road (District Government) ▪ Function: Secondary Local Road ▪ Class: II ▪ SPPJ: JKC
3.	Vd range (km/h)	10-30

These technical design criteria were made based on technical data on road conditions by taking into account the principles of the 2021 Highway Geometric Design Guidelines. The results of the analysis of the element values for the geometric design criteria of vertical alignment techniques can be seen in table 2. The Bangkonol TPA operational road has a maximum slope gradient of 8% following the contour of the existing land. This road serves class II vehicles with a design speed of 10-30 km/hour. The road type is 2/2-TT, with a lane width of 3.0 m.

Table 2. Technical Design Criteria

No.	**Elements**		**Criteria Value**
1.	Vd, Km/hr		30km/h
2.	Grade max, %		8 %
3.	Elongated roughness		0.29
4.	Lmin of vertical curvature, m, or K value		18m or Convex > 2 Concave > 6
5.	Longest straight section length (Max), m		1200
6.	Road Type and Dimensions	Road Type	2/2-TT
		Lane width, m	3.0
		Shoulder width, m	1
		Median width, m	-
		Verge width, m	-
7.	Pavement Type		Rigid
8.	The shortest distance between plot intersections, Km		0.3
9.	The shortest distance between parcel access, Km		0.5

4.2 Vertical Alignment Design

The vertical alignment design is made up of straight lines with different slopes, which are still within the permissible limits, then connected by concave vertical curves (*Sag*) or convex vertical curves (*Crest*). Making a vertical alignment longitudinal profile, try to the point of intersection (PV) optimally; the line must be very close to the subgrade soil profile. The results of the design calculations produce seven convex vertical curves and eight concave vertical curves. The height of the vertical alignment of the road at each location along the route is largely controlled by the features that the road crosses.

The design should consider the impact of the cross profile of the road body that borders or intersects the road, which can affect the vertical geometric design, especially when considering drainage and changes. First, the transverse or superelevation profile. Second is the top position of the cross-slope of the road, and third is the addition or reduction of traffic lanes. Lastly is the angle between the path and the object. Further on hilly terrain, subsurface drainage may be required to ensure the pavement construction is above the groundwater table. On the other hand, based on cost considerations, it is possible to reduce the height of the free space above the groundwater level. Arterial roads must be flood-free, but under certain conditions, water on the pavement for a moment in rainwater is still acceptable.

On roads equipped with medians, caution should be exercised when choosing the location of the grading points, especially on roads that will be built in stages, because the position chosen has an impact on earthworks, drainage, aesthetics, and stages of work. In addition, it is necessary to consider the median path's further development. Usually, a one-lane road with a unidirectional transverse slope is built first, and as traffic volume increases, a second lane is built.

Table 3. Vertical Curve Calculation Results

Convex Vertical Curve Design (Crest*)*							
Point	**PV 2**	**PV4**	**PV5**	**PV8**	**PV9**	**PV14**	**PV15**
A (%)	-7	-5,2	-7,36	-4,6	-2,48	-7,16	-4,32
Based on Stopping Sight Distance (SSD)							
Vd(km/hrs)	30	30	30	30	30	30	30
Jph(m)	35	35	35	35	35	35	35
K(m)	2	2	2	2	2	2	2
L(m)	14	10,4	14,72	9,2	4,96	14,32	8,64
Based on Passing Sight Distance (PSD)							
Vd(km/hrs)	30	30	30	30	30	30	30
Jpm(m)	120	120	120	120	120	120	120
K(m)	17	17	17	17	17	17	17
L(m)	119	88,4	125,12	78,2	42,16	121,72	73,44
K KDS minimum (m)	2	2	2	2	2	2	2
K SSD (m)	2	2	2	2	2	2	2
K PSD (m)	17	17	17	17	17	17	17
K used	17	17	17	17	17	17	17
Check	ok	ok	ok	ok	ok	ok	ok
L used (m)	**119**	**89**	**126**	**79**	**43**	**122**	**74**

Table 4. Vertical curve (sag) calculation

Concave Vertical Curve Design (*Sag*)								
Point	**PV1**	**PV3**	**PV6**	**PV7**	**PV10**	**PV11**	**PV12**	**PV13**
A (%)	2,52	6,92	2,72	1,16	0,6	4,52	5,16	7,6
Based on Vehicle Illumination Sight Distance								
Vd(km/hrs)	30	30	30	30	30	30	30	30
K(m)	6,94	6,94	6,94	6,94	6,94	6,94	6,94	6,94
L(m)	17,50	48,06	18,89	8,06	4,17	31,39	35,83	52,78
Based on Driver Comfort								
Based on Drainage Factor, If the L value is more than 750 meters, it should not be used								

Based on Appearance Factor								
Minimum 30 meter								
K KDS minimum (m)	13	13	13	13	13	13	13	13
K used	6,94	6,94	6,94	6,94	6,94	6,94	6,94	6,94
Check	ok	ok	ok	ok	ok	ok	ok	ok
L used (m)	**30**	**48**	**30**	**30**	**30**	**31**	**36**	**53**

From the results of table 3 and table 4, the results of calculation above are obtained to determine the length of the vertical alignment curve at the bend STA 0+000 – STA 0+400. This calculation is guided by the Circular Letter of the Director General of Highways of the Ministry of Public Works and Public Housing regarding the 2021 Highway Geometric Design Guidelines. The results of the calculations are presented in figure 4.

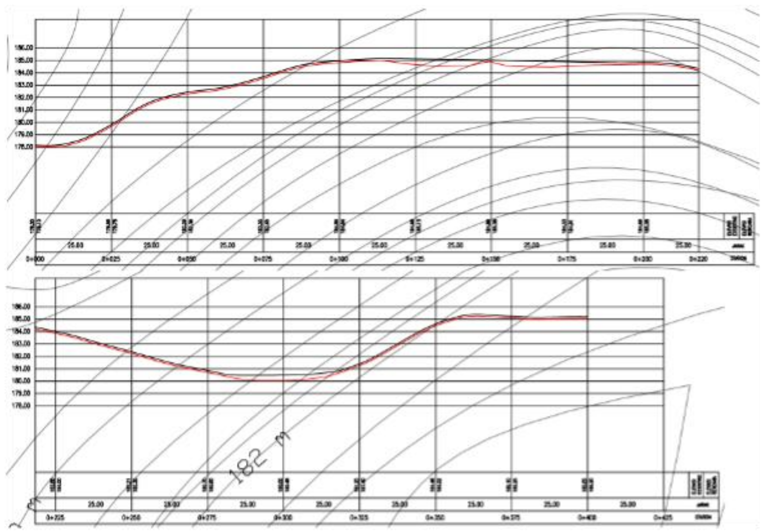

Figure 4. Drawing of Vertical Alignment

5. Conclusion

From the results of this study, the vertical alignment calculation data obtained, there are seven convex vertical curves and eight concave vertical curves on the Bangkonol TPA operational road, Pandeglang Regency. The technical design criteria are set at a design speed of 30 km/hour, the maximum elongated road Grade value is 8%, and the vertical Lmin is 18m. The geometric calculation of the TPA operational road is based on the Highway Geometric Design Guidelines, which can meet the safety and comfort aspects of drivers. The results of this design are expected to be able to serve the accessibility in and out of vehicles that will operate at the TPA Bangkonol well.

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