3D Modeling Ground Level Surface for Roadway Horizontal Alignment Design

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Abstract. Road geometric design requires topographic data of road alignment plans. National Digital Elevation Model (DEMNAS), published by the Geospatial Information Agency, could be used as preliminary data to design horizontal and vertical alignments. This research aims to: the site plan of Polinela 2nd campus geometric correction, 3D modeling of ground-level surface based on DEMNAS, overlaying the road alignment plan on 3D modeling of ground-level surface, identifying the point of intersection, calculating parameters of road bend, describing the ground level profile of the roads alignment plan. Geometric correction, modeling, computing, and drafting were formulated with Autodesk Civil 3D software. The roads plan, which had a bend in its segment, was analyzed. The roads plan would be modeled on a 3D surface to be analyzed for its horizontal alignment parameters, including bend angle, bend radius, circular arc length, transition arc length, superelevation, and the appropriate type of bend. The horizontal alignment parameter analysis refers to the road geometric planning standards set by the Ministry of Public Works and Public Housing. The results show that the four road segments that had to be analyzed for the bend parameters and the appropriate type of bend were full circle (FC) and spiral spiral spiral (SCS).

1. Introduction

The road is a land transportation infrastructure that includes all parts, including complimentary constructions and equipment intended for traffic on the ground surface, above, or below ground level except for railroads, lorries, and cableways [1].

Politeknik Negeri Lampung (Polinela) has compiled a site plan of campus II that considers the direction of the Kota Baru area of Lampung Province, the movement network plan, the future development scenario Polinela, and other factors [2]. Apart from the layout of the building, the site plan visualized the road alignment plan (Figure 1).

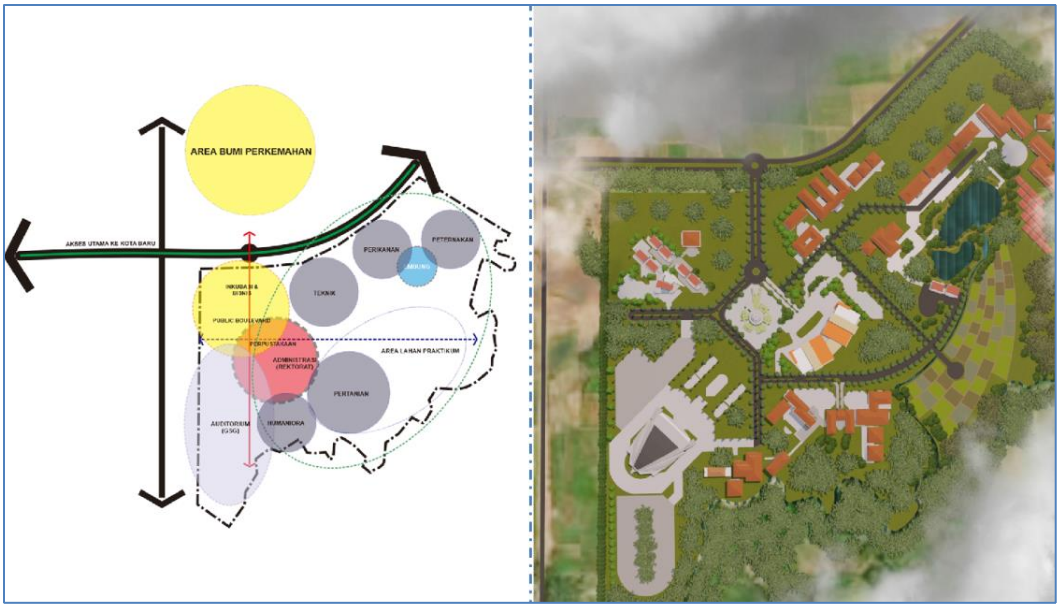


Figure 1. Road Network Plan of Polinela Campus II

The road network plan within the campus area needs to be planned appropriately following the standard set out in the geometric planning of the road, covering 3 (three) criteria: vehicles, traffic volume, and speed [3–7]. These three criteria would determine the road geometry, both horizontally and vertically. Horizontal alignment was the initial part of the geometric planning of the road, which includes planning the bend of the road along its trace.

There were 2 (two) essential things in planned road bends that must be determined based on field conditions, namely the shape of the curve and superelevation [5,8]. Based on the arc components that made the bend up, the shape of the bend was divided into 3 (three) conditions. They were full circle (FC) bend formed by whole circular arc, spiral–spiral (SS) bend formed by transitional arches, and spiral circle spiral (SCS) bend formed by transitional arcs and circular arc [9–11]. At the same time, superelevation was a transverse slope at the bend, which served to offset the centrifugal force received by the vehicle when the vehicle passed through the turn at the design speed [12,13].

Topography was an essential factor in the geometric planning of roads that would significantly affect the volume of earthworks (excavations and embankments), which would affect the investment costs of road construction [11,14,15]. Along with the development of technology, especially in geomatic, topographic data was not only in the form of coordinate point vector data but has developed towards digital data, namely digital elevation model (DEM). In the national scope of Indonesia, the Geospatial Information Agency has provided DEM, which was accessible to all parties, namely DEMNAS data which in raster type spatial data with good accuracy [16,17]. DEMNAS produced a minimum of 0.148 meters in residential areas [18].

Related to DEMNAS data used for geometric road planning, available modeling software for DEMNAS data processing and geometric road modeling was, such as Global Mapper, ArcGIS, AutoCAD, Autodesk Civil 3D, and others. The advantages of using it in geometric road planning were minimizing the cost of measuring the topography of the planned area, horizontal alignment planning became faster and more precise, and changed parameter values in the scheduled of road alignment would directly change all components of the planning, including situation map, alignment, longitudinal sections, cross-sections, and other desired design products.

2. Methods

This research was conducted from May to September 2021 on the campus II of Polinela, located in Kota Baru, Province of Lampung. The research method used is software modeling. The object of research is the road trace plan, which is visualized in Polinela Campus II's site plan.

Data were obtained from various sources, including Geospatial Information Agency and Polinela. Through the official website of BIG, DEMNAS was downloaded within an exciting area which provided from map of Polinela Campus II. The road trace was digitized based on the site plan map of Polinela Campus II. DEMNAS and the road path were projected in the same coordinate projection to be overlayed. The ground-level surface of the Campus II area was modeled from DEMNAS as a background in horizontal alignment design that referenced the site plan of road trace.

The road trace described the positioning of start, finish, and points of intersection (PI) between tangents. These data would be referenced in horizontal alignment modeling on the surface generated from DEMNAS.

The modeling designed parameters consisted of: plan speed, the radius of the circle, length of the process, length of spiral, and superelevation that modeled to three types of road bend were full circle (FC), spiral circle spiral (SCS), and spiral (SS). The type of bend that is most inlined to Bina Marga (BM) standard was chosen in each angle which is designed to refer to the point of intersection (PI) position (X, Y, Z) that would be used to draft bend and superelevation diagram.

The following design criteria based on the geometric design standards manual (Bina Marga Standard) were assigned to the horizontal geometry of the center line and also to the profile and cross-section of the roadway were: design speed 30 km h^{-1} average superelevation rate 2%, maximum superelevation rate 10%, crown road type, coefficient of friction 0.166, carriageway width 4 x 3.5 meter with 2-meter separator.

3. Results and Discussion

3.1. Point of Intersection

Digitized site plan resulted in road trace that described the positioning of start, finish, and points of intersection (PI) between tangents illustrated below (Figure 2).

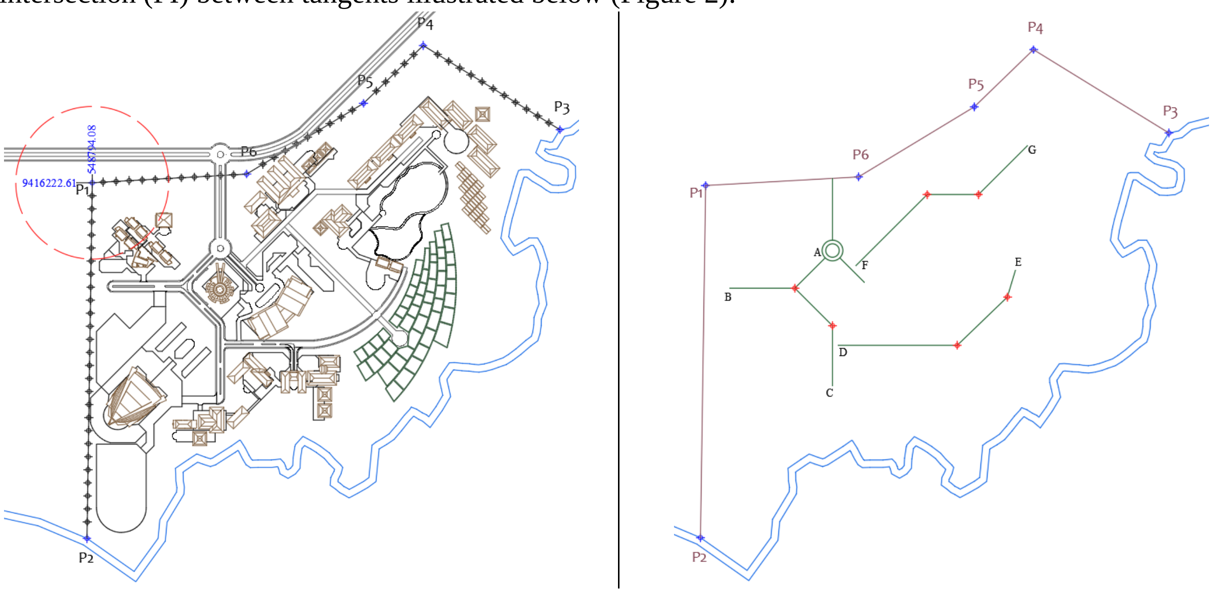


Figure 2. Position of start, finish, and PI

In this research, the object of traces are AB, AC, and BC that geographically could be defined as the position of start, finish, and points of intersection (PI) between tangents (Table 1).

Table 1. The object of traces are AB, AC, and BC that geographically could be defined as the position of start, finish, and points of intersection (PI) between tangents

Trace	PI	UTM Zone 48S		Tangent
		X	Y	
AB	PI_1	548.966,26	9.416.023,99	A-PI_1 and PI_1-B
AC	PI_1	548.966,26	9.416.023,99	A-PI_1 and PI_1-PI_2
	PI_2	549.038,99	9.415.951,24	PI_1-PI_2 and PI_2-C
BC	PI_1	548.966,26	9.416.023,99	B-PI_1 and PI_1-PI_2
	PI_2	549.038,99	9.415.951,24	PI_1-PI_2 and PI_2-C

3.2. Ground Level Surface

Overlaying traces on DEM resulted from an elevation of start, finish, and points of intersection (PI) between tangents (Figure 3). The slope value of the deviation could be calculated based on flat distance and difference in height between points.

The elevation of start, finish, and a 3D analysis calculated points of intersection (PI) between tangents to input DEMNAS cell values to facts overlayed. The difference of height (dz) and flat distance (dh) could calculate the ground surface at tangents slope (Table 2). The value of dz was determined by the difference of elevation between the two points. In comparison, the value of dh was determined by abscissa and ordinate between two points.

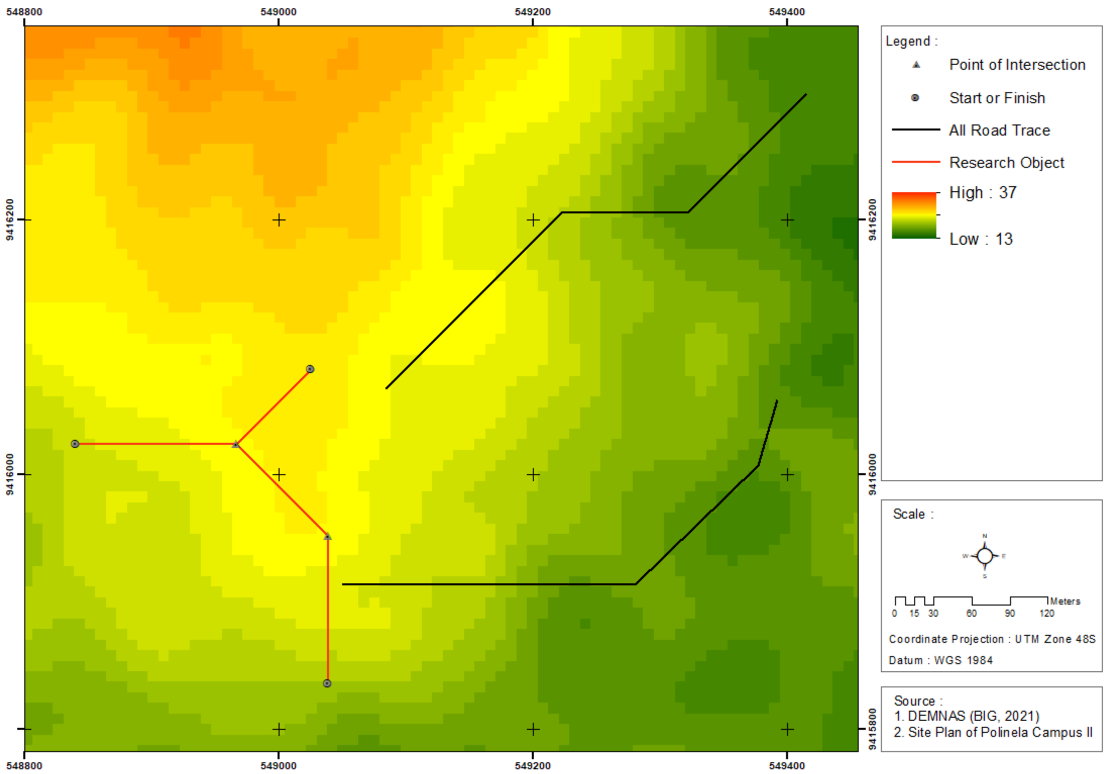


Figure 3. Overlaying Road Segment on DEMNAS

Table 2. The difference of height (dz) and flat distance (dh) could calculate the ground surface at tangents slope

Tangent	dh (m)	dz (m)	Slope
A-PI_1	82.99	-1.00	-0.0120
PI_1-B	126.47	-2.00	-0.0158
PI_1-PI_2	102.86	0.00	0.0000
PI_2-C	115.96	-3.69	-0.0318
B-PI_1	126.47	2.00	0.0158

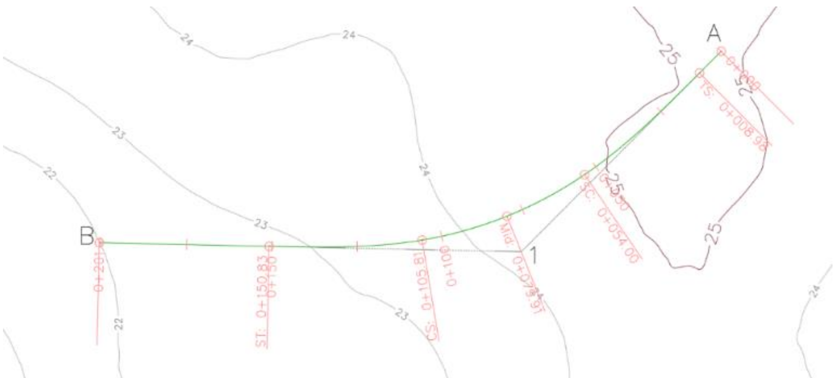
3.3. Bend Modeling

The assumptions used in the bend modeling were 30 kph in speed design, 2% for e_n, and maximum side slope (e_{max}) 10%. These values referred to BM standard with local road criteria on flat to hilly topographic terrain. Each trace (segment) of the road (AB, AC, and BC) were modeled to determine the type and parameters of bend on the point of intersection (PI).

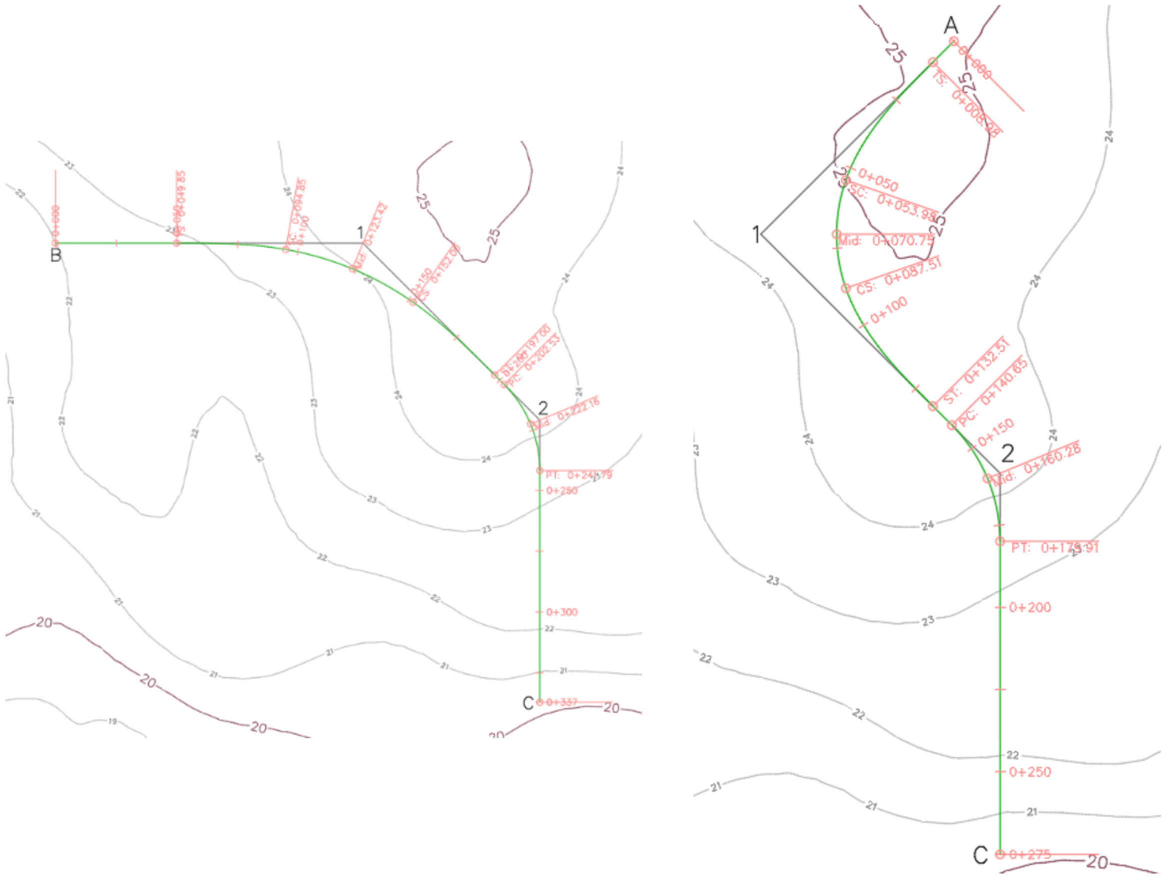
Bend modeling of segment AB determined that type of bend on PI_1 was SCS which parameters were 45 m for a length of spirals (LS), the radius of circle 120 m, and total length of bend reach 141.85 meters (sta. 0+008.98 to 0+150.83).

Bend modeling of segment AC determined that type of bend on PI_1 was SCS which parameters were 45 m for a length of spirals (LS), the radius of circle 50 m, and total length of bend reach 123.53 meters (sta. 0+008.98 to 0+132.51). While the type of bend on PI_2 was FC which parameters 50 m and 39.26 m for a radius of circle and length of bend (LC), 39.26 m length was measured from sta. 0+140.65 to 0+179.91.

Bend modeling of segment BC determined that type of bend on PI_1 was SCS which parameters were 45 m for a length of spirals (LS), the radius of circle 130.05 m, and total length of bend reach 147.15 meters (sta. 0+049.85 to 0+197.00). The type of bend on PI_2 was the same as the AC segment (Figure 4).



Horizontal Alignment of Segment AB

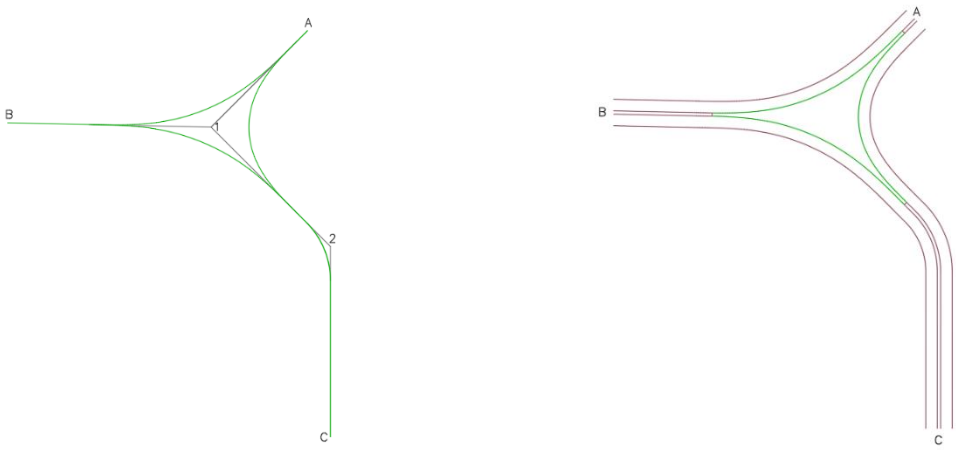


Horizontal Alignment of Segment BC

Horizontal Alignment of Segment AC

Figure 4. Bend Modeling in Autodesk Civil 3D

The results of the horizontal alignment modeling above were plotted on the ground surface to produce a flat alignment plan. The centerline of horizontal alignment was offset to reach the typical roadway cross-section, in this case, using a 4 x 3.5-meter carriageway width with a 2-meter separator (Figure 5). The offsetting of the centerline above resulted from a horizontal alignment plan of the roadway for AB, AC, and BC segments in the same surface field.



Center Line (CL) of Horizontal Alignment

Result of Offsetting CL

Figure 5. Horizontal Alignment Plan

3.4. Ground Level Along Trace of Road

Modeling surface from DEMNAS and horizontal alignment plan in Autodesk Civil 3D could describe ground level surface along the center line of flat alignment plan. The ground-level surface would be drafted in the long section from the start to the finish point of each segment (Figure 6).

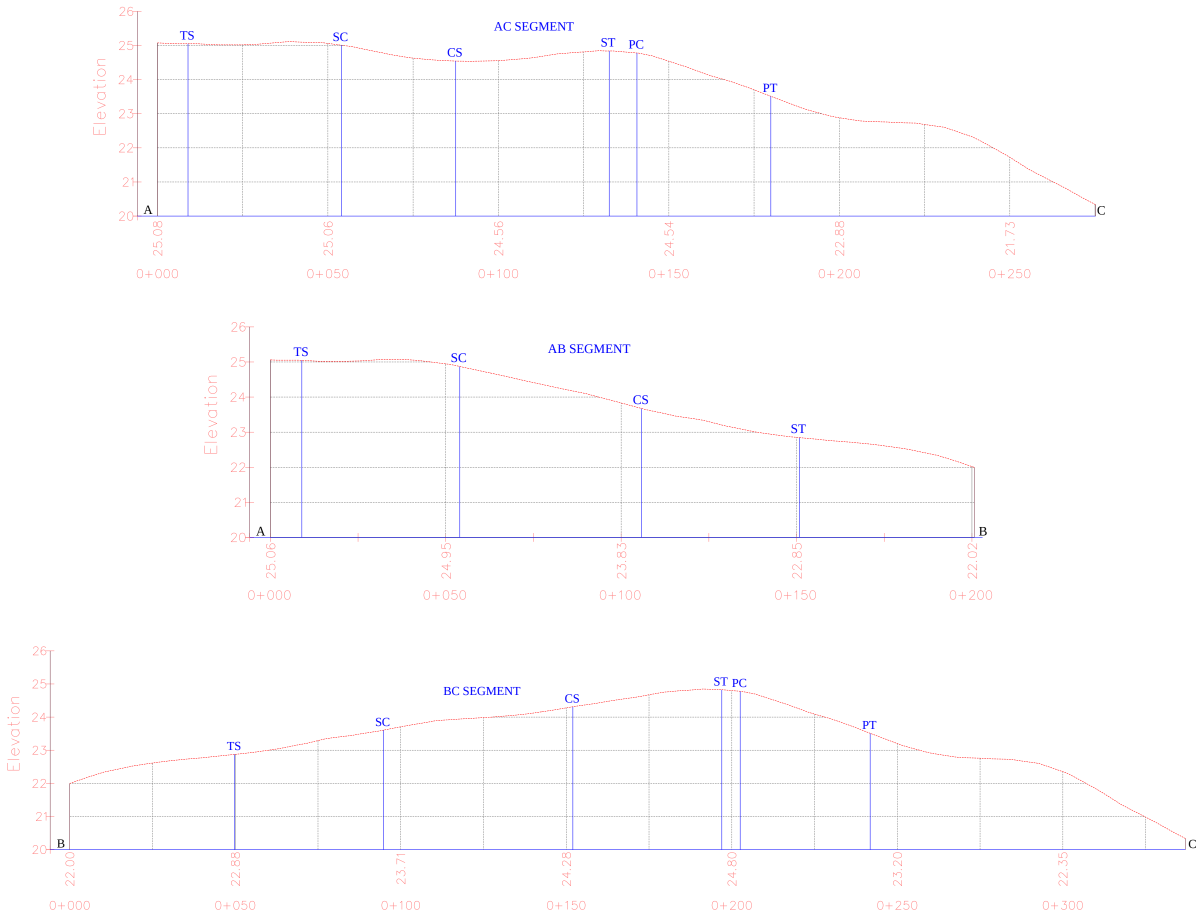


Figure 6. Ground Level Surface Along with CL of Horizontal Alignment

The long roadway segments section above gave important information of horizontal alignment were 1) original ground level along the center line of each segment and 2) original ground level of each bend parameters, TS – SC – CS – ST (SCS type) and PC – PT (FC type).

The long section of the AC segment described that ground-level surfaces were flat to hilly and through 2 (two) types of bend, SCS, and FC. The character in SCS type (TS to ST point) was relatively flat, so this section could design the vertical alignment that minimized excavation and embankment work. The AB segment's extended area was similar to the AC segment but along the segment just through 1 (one) type of bend, FC.

The long section of the BC segment described that the ground level surface was trough 2 (two) types of bend, SCS, and FC. The character in SCS type (TS to ST point) was hilly, uphill from TS to ST. Along the FC segment, the surface also was hilly, downhill from PC to PT, when the design of vertical alignment has to notice AC segment because FC section in BC segment is the same FC section in AC segment.

This information would be needed to design and model vertical alignment that would affect roadway safety and investment.

4. Conclusions

Based on the results of research and discussion, it can be concluded that the type of roadway bend was spiral – circle – spiral (SCS) and full circle (FC) for 3 (three) segments of the roadway as the research object. AC segment consisted of two types of bend, SCS, and FC, with a total length of angle, reaching 123.53 meters in SCS type and 39.26 m length in FC type. AB segment consisted of one kind of bend, was SCS with a total length of angle reach 141.85 meters. The BC segment consisted of two kinds of the curve, SCS, and FC, with a full bend, reaching 147.15 meters in SCS type and 39.26 m length in FC type. The ground-level surfaces of the centerline of the roadway were flat to hilly. The flat to hilly surfaces were revealed in AC and AB segments, and the fully hilly surface was in the BC segment.

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