ISSN 2347 - 3983
Volume 8. No. 8, August 2020
International Journal of Emerging Trends in Engineering Research
Available Online at http://www.warse.org/IJETER/static/pdf/file/ijeter46882020.pdf
https://doi.org/10.30534/ijeter/2020/46882020

Speed of Plan as Parameter for Selection of Bend Types in Highway Geometric Planning

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ABSTRACT

Road geometry that is in accordance with traffic demands and in accordance with the class and function of the road is expected to meet the level of comfort and safety of the rider. One of the geometric planning for the road is the selection of the shape of the bend based on the speed data plan used. The purpose of this study is to analyze the planning of the type of bend selection based on the speed of the plan on a road section. Geometric survey method is carried out to get geometric data of roads that function as inter-city collector roads with class IIIA road specifications, pavement width of 3.5 m, with planned speed (Vr) of 50 km / hour. Road geometric analysis using Guidelines and Procedures Geometric Planning of Inter-City Roads (IRCM, Indonesian Road Capacity Manual) in 1997. The planned bend is the Full Circle Bend. From the results of surveys and geometric analysis of roads that have a slope of 2% can be passed by vehicles with a planned speed of 50 km / hour. Full circle bend can and is safely used on roads that have a vertical alignment (transverse slope) of an average of 3.67%, horizontal alignments of various sizes Δ2 = 4.6871o; Rr = 819 m; Tc = 33.500 m; Ec = 0.685 m Lc = 66.985 m Ls' = 41.6 m emax = 10 ; en = 2 %, widening of the pavement at the bends, amounting to 1.875 m, and has value E < Eo = 0.82 m < 16.5 m.

Key words: full circle bend, geometrics, road collector, speed of plan

1. INTRODUCING

A good highway planning, its geometric shape must be determined so that the highway can provide optimal services for its users in accordance with its basic functions. Geometric highway in the form of Horizontal Alignment and Vertical Alignment. In Horizontal Alignment planning, there are three types of bends used, namely Full Circle (F-C), (Spiral - Circle - Spiral, S-C-S) and Spiral-Spiral (S-S). Whereas Vertical Alignment consists of Convex and Concave Vertical Alignments [1]. For example, grade and slope. How does the Full Circle bend on the collector road with hilly terrain conditions that have an average cross-slope of 3.67% planned on one of the road segments, then in this study survey and calculation are carried out aimed at getting the geometric size of the road and the Full Circle bend so that the road can function in accordance with the class and meet the level of comfort and safety expected by the driver.
Route planning of a complete road segment, including several elements that are adjusted to the completeness and basic data available or available from the results of field surveys and have been analyzed, and refer to the applicable provisions [2].

2. LITERATURE REVIEW

Geometric road planning is part of road planning that focuses on physical form planning so that it can fulfill the function of the road, namely providing optimum service in traffic flow. From the geometric planning the road will produce a safe, efficient infrastructure, in the service of traffic flow that maximizes the ratio of usage levels and implementation costs. It can be said that the space, shape and size of a good road is one that can provide a sense of security and comfort to road users [3].
In road geometric planning, several notions of speed include: it has been defined as the maximum speed of a vehicle in prevailing traffic flow and good weather. In other studies, this speed has been defined as vehicle speed under free flow condition [4]. Plan speed (Vr) is the speed chosen for the planning needs of each section of the highway such as bends, slope, visibility, and others [3].
Several previous studies on road geometry and driver safety in driving that are relevant to this study include the following conclusions:
Aljanahi et al., [5] stated that Road crashes are complex events and are influenced by many factors such as road geometric design, traffic volume and composition, speed differentials between vehicles of the same class and different classes, weather, motivation for travelling, driver's physical and mental conditions and so on.
On horizontal curves, radius, curvature, length of the curve, degree of the curve, superelevation, and lateral friction can influence on vehicle speed. The radius of curve is the most influential parameter on vehicle speed on horizontal curves [6], [7]. On tangents the effect of parameters such as the slope of tangent, lane width, the radiuses of previous and following curves, tangent length, and etc. should be explored [8]. Lane width and posted speed limit are effective variables. In previous studies the existence of free flow condition for speed data collection has been noticed. Under free flow codition, a vehicle speed is not affected by other vehicles. Therefor, effective variables are geometric elements [9]. Vehicles do not reach to their maximum speed at midpoint of tangent. [10], [11].
To evaluate the consistency between drivers behavior and safety speed against skedding and rollover conditions, depending on the horizontal alignment of the road. Thereafter, the critical points within same road were thoroughly assessed by an in-depth analysis to identify the existence of other factors that affected the road safety, such as vertical alignment, sight distance, junctions, etc.

The analysis can be useful for several possible applications to historical roads whose design values are unknown: compare the posted speed limits applied in horizontal curves with the estimated safety speed and review them, if necessary and confirmed by the assessment of safety against other criteria; consider the need for further interventions other than the posted speed limits if they demonstrated to be breached by significant fractions of drivers; rank the regional roads with respect to the safety indices in order to plan a review of posted speed limits and other possible interventions aimed at increasing the road safety. A natural extension of this analysis is to compare the estimated safety speed values with accident data to verify which percentile is significantly correlated with the actual accident occurrences and to adjust the hypothesized values of the parameters used to determine the safety speed, such as side friction and superelevation, to maximize the correlation with the accidence occurrence or with a more general indicator of potential accidents. Future development of the proposed study concerns using actually travelled trajectories instead of the available commercial graph for computing the safety conditions. On this regard, the analysis of the distributions of FCD on the cross sections of the roads enables individuating the average traveled trajectory for different lanes and computing a bundle of most likely traveled trajectories corresponding speed profiles which can then be compared with the speed profiles imposed by safety conditions [12].
Initial speed and slope of tangents were the most important variable statistically on both of downgrade and upgrade tangent. The passenger cars have more speed than heavy trucks on slopes. By looking at t-values of this variable in equations it was concluded that the difference between these two classification of vehicles statistically significant at significance level of 0.05 [13].
The influence of geometric design characteristics on the level of safety on a four-lane divided intercity roadway in India, operated under heterogeneous traffic condition was studied. Bi-directional data were used for developing models by statistical modelling approach. Poisson and NB regression models were developed for both year-wise and direction-wise. Based on the developed models, the following conclusions are drawn. Geometric characteristics were observed to vary for both directions of travel. These variations affect the traffic characteristics thereby decreasing the level of safety, resulting in more crashes. The study resulted in a better understanding of the effect of geometric design characteristics on crash frequency and observed that operating speed contributes significantly to the number of crashes. The study recommends that the value of horizontal curvature, one of the main highway design characteristics, should be kept minimum as much as possible from the safety point of view. This will lead to maintaining safe operating speed along the highway [14].

1.1 Bend

In order for the vehicle to be stable as it passes through a bend, it is necessary to make a transverse slope on the bend called superelevation (e). When the vehicle passes through the superelevation area, there will be a friction in the direction of the crossing of the road between the vehicle tire and the asphalt surface which creates a transverse friction force. The comparison of the transverse friction force with the normal force is called the transverse friction coefficient (f). To avoid accidents, for a certain speed can be calculated the minimum radius for maximum superelevation and the maximum coefficient of friction. For calculations, use emax = 10 % [15].

$$R\ min. = \frac{Vr^2}{127\ (e\ max. + f\ max.)} \quad 1)$$

$$fm = 0.24 - 0.00125 \times Vr \quad 2)$$

$$D\ max. = \frac{181913.53\ (e\ max. + f\ max.)}{Vr^2} \quad 3)$$

R_{min} : minimum bends radius, (m)
V_R : vehicle speed plan, (km/hour)
$e_{max.}$: maximum superelevation (%)
fmax. : coefficient of maximum transverse friction
D : degre of curvature
$D_{max.}$: maximum degree

1.2 The transitional Arch

Based on the maximum travel time (T = 3 seconds), to cross the transition curve, the length of the curve:

$$Ls = \frac{Vr \times T}{3.6} \quad 4)$$

Based on the anticipation of centrifugal force, the Shortt Modification formula is used:

$$Ls = \frac{0.022\ Vr^3}{Rc\ C} - 0.727\ \frac{Vr\ e}{C} \quad 5)$$

Based on the level of achievement of slope changes:

Where:

$$Ls = \frac{(em - en)\ Vr}{re} \quad 6)$$

T : travel time = 3 seconds
Rc : circle arc radius (m)
C : change in speed 0.3-1.0 recommended 0.4 m/sec^2
Re : level of achievement of change slope crossing
For VR $\leq$ 70 km/hour, re max. = 0.035 m/m/sec.

for VR $\geq$ 80 km/hour, re max. = 0.025 m/m/sec.

e : superelevation
e_m : maximum superelevation
e_n : normal sperelevation

FC (Full Circle) is a type of bend that only consists of parts of a circle. FC bends are only used for large R (radius) to prevent fractures, because with a small R, superelevation (a large crossing of the road at the bend) is needed.
In addition to bend planning as part of Horizontal Alignment, there are things that need to be considered in Vertical Alignment planning namely [5]:

a. Plan speed (Vr) is the speed chosen for the planning needs of each section of the highway such as bends, slope, visibility, and others.
b. Maximum slope is based on the speed of a fully loaded truck capable of moving at speeds of no less than half the original speed without having to use low gear.
c. Minimum Slope On roads that use curb at the edge of the pavement, a minimum slope of 0.5% needs to be made for the side slope requirements, because the slope of the road with curb is only enough to drain the water sideways.
The following Fig.1 is a Full Circle bend planning flow chart:

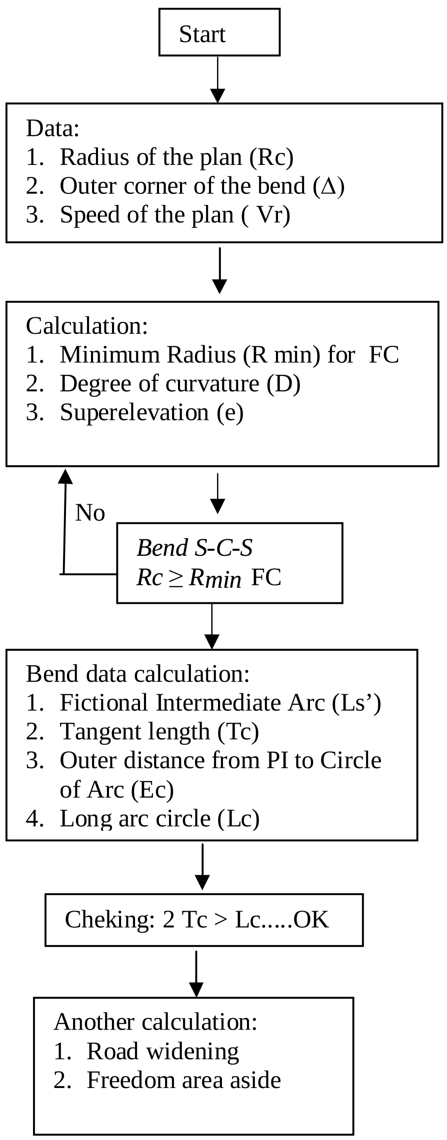

Figure 1: Flow chart of Full Circle Bend planning

3. RESEARCH METHODOLOGY

Geometric Survey The existing road was carried out on the Mancak - Anyer road, Banten, Indonesia, 2019 to obtain primary data in the form of:

a. Horizontal alignment is a road alignment consisting of a straight line (Tangent), determining the station's starting point, and the distance between stations.
b. Vertical alignment depicting high and low road to the original land surface.

4. RESULT AND DISCUSSION

Table 1: The Results of the Calculation Distance between Points

POINT	COORDINATE	
	X	Y
Begining	50002.210	49982.545
P	49854.055	50275.280
P	49645.418	50470.959
B	49511.419	50619.006

Source: Result from field Survey, 2019

Table 2: Distance between Stations

Stations	Length
Begining- PI_1	328.0909 m
PI1-PI_2	286.0413 m
PI_2-B	199.6838 m
Distance length d1-B	813.8160 m

Source : Result calculation, 2019

Vertical Alingnment

Table 3: Elevation and Slope

No.	Point	STA	Original ground elevation	Slope (g)
1	Begining	0+000	501.4	1.93%
2	PV1	0+279.17	506.8	1.54%
3	PV2	0+565.06	511.2	1.04%
4	B	0+746.81	513.1	

Source: Result from field Survey, 2019

Table 4: Maximum Allowable Slope

Maximum Slope %	3	3	4	5	8	9	10	10
Vr (km/h)	120	110	100	80	60	50	40	<40

Source: Procedures Geometric Planning of Inter-City Roads,1997, directorate general of hihway, department of public works

Table 5: Transverse Slope Calculation Results

STA			Elevation		Δ	%	Area Classific
			Left	Right	Transverse Slope	Slope	
0	+	0	499.24	500	0.86	5.73	Hilly
0	+	100	503.48	503.96	0.48	3.20	Hilly
0	+	200	504.28	506.88	2.60	17.33	Hilly
0	+	300	505.95	506.29	0.34	2.27	Flat
next							
0	+	400	510	509.74	-0.26	1.73	Flat
0	+	500	512.5	512.63	0.13	0.87	Flat
0	+	600	511.12	511.23	0.11	0.73	Flat
0	+	700	510.41	510.58	0.17	1.13	Flat
0	+	800	513.42	513.42	0	0.00	Flat
Total						**32.99**	

Source : Analysis result, 2019

Horizontal Alignment

Bend PI2

$\Delta 2 = 4.6871^{o}$; Vr = 50 km/hour
Radius (R_{min}) = 80 m
Planned using the Full Circle bend, use
R_r = 819°. Used elevation (e) = 0.053m

1. **The Transitional Arch** (Ls)

The largest Ls value is used that is 41.6 m, because at the Full Circle bend there is no transition curve (Ls), the Ls that occur are considered to be fictitious.

2. **Bend Calculation**
   a. Distance between point TC – PI_2: 33.500 m
   b. Distance from PI_2 to circle arc, Ec = 0.685m

c. Long arc circle TC – CT: Lc = 66.985 m

Full Circle bend conditions, LT= The results of the calculation of widening of the pavement at the bend, amounting to 1.875 m. Score E < Ec = 0.82 m < 16.5 m.
Lc = 66.985 m; 2Tc > Lc; 2 x 33.500 > 66.985.
67 > 66.985............Ok, Then the Full Circle bend can be used.

PI2 Bend uses the Full Circle type with the following calculation result:
Δ2 = 4.6871o; Rr = 819 m;
Tc = 33.500 m; Ec = 0.685m
Lc = 66.985 m Ls' = 41.6 m,
elevation (emax) = 10; enormal =2%.

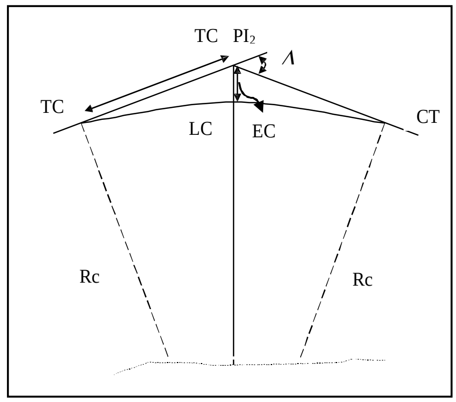

Figure 2 PI_2 Bend

Source : Analysis result, 2019

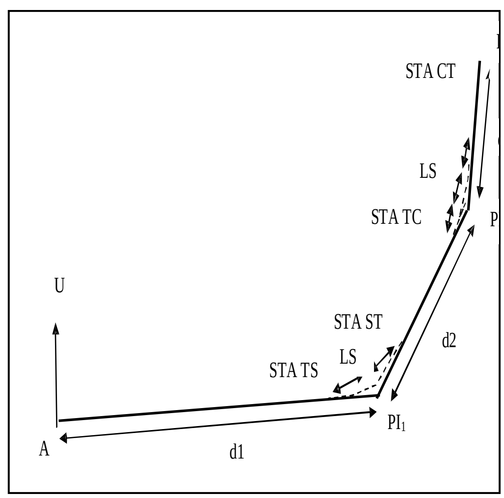

Figure: 3 Stationing

Source : Analysis result, 2019

Table 6: Vertical Arch Elevation and Stationary Vertical Arch

POINT	PV1			PV2		
		Vertical Arch Elevation (e)	Stationary (Sta) Vertikal Arch		Stationary (Sta) Vertikal Arch	Vertical Arch Elevation (e)
A	Slope Gradient (A) = 0.39 %	506.40m	0+258.340 m	Slope Gradient, (A) = 0.5%	0+544.230 m	510.880 m
B	L_V = 41.66 m	506.60 m	0+268.755 m	L_V = 41.66 m	0+554.645 m	511.046 m
C	Ev = 0.02 m	506.82 m	0+279.170 m	Ev = 0.026 m	0+565.060 m	511.230 m
D	Y = 0.005 m	507.96 m	0+289.585 m	Y = 0.006 m	0+575.475 m	511.310 m
E		507.12 m	0+300 m		0+585.890 m	511.420 m

Source : Analysis result, 2019

5. CONCLUSION

From the results of survey and geometric analysis, a road with a traffic lane width of 3.5 m and a slope of 2% can be passed by a vehicle with a planned speed of 50 km / hour. Full circle bend can and is safely used on roads that have horizontal alignments with sizes Δ2 = 4.6871o; Rr = 819 m; Tc = 33,500 m; Ec = 0.685 m Lc = 66.985 m Ls' = 41.6 m; e max = 10; en = 2%, widening of the pavement at the bend, amounting to 1,875 m, and has an E <Ec = 0.82 m <16.5 m. In addition to the speed of the plan as a parameter in the selection of the type of bend, especially on the road in hilly areas, the radius of the bend, changes in road slope and driver behavior generally have a significant influence on driver safety.

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