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RIGID PAVEMENT PLANNING IN TRAFFIC: CASE STUDY IN CIHERANG ROAD AND PEMUDA ROAD, BOGOR REGENCY, INDONESIA

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Rd Ciherang and Rd Pemuda, Dramaga Subdistrict, Bogor Regency, are located in a densely populated area which connects Rd Raya Dramaga and Rd Dramaga Ring. The existing condition of the road is in the form of flexible pavement or asphalt, but there are several points that have been damaged. Damage is in the form of longitudinal cracking, cracks and holes. The purpose of planning rigid pavement is to improve the surface layer of the road smoother and provide comfort, smoothness for road users. The method used is to calculate the thickness of the plate and geometric analysis of the road. The basis for choosing rigid pavement is due to its location in the mountains and poor subgrade conditions. The basic condition of rigid pavement strongly supports the movement of heavy vehicles in locations which are planned for the outer ring road. Because the geometric conditions of the road are winding and up and down, Spiral-Circle-Spiral and Full-Cyrcle planning is highly recommended. Fatik and erosion damage must be less than 100%. This is to get the results of the calculations that have been done. Rigid Pavement is planned and geometric analysis to provide comfort and smoothness for road users. In this study, a pavement thickness of 18.5cm was produced from the results of calculations using Bina Marga Method. Transverse connection using dowel diameter 25mm, length 450mm, spacing 300mm. Longitudinal connection using tie bars with a diameter of 16mm, a length of 700mm and a distance of 600mm. The results of the geometric analysis obtained five horizontal alignment forms, namely the spiral-circle-spiral (SCS) PI-1 bend with a bend length of 153.35m. The PI-2 bend is spiral-circle-spiral (SCS) with a bend length of 233.21m. The PI-3 bend is full circle (FC) type with a bend length of 174.19m. The PI-4 bend is full circle (FC) type with a bend length of 68.11m. Full circle (FC) type PI-5 bend with a bend length of 66.47m.

Key words: road damage, rigid pavement planning, Bina Marga Method, road geometric

INTRODUCTION

Roads that are in good condition will make traffic smooth. Roads with slightly bumpy conditions cause the vehicle speed to be reduced to avoid vibrations on the vehicle wheels. Roads with poor condition and badly damaged vehicle speed slows down and tends to slow down. The condition of the road surface is very bad and heavily damaged on the road at the location of this study. Roads are infrastructure that connects one area to another which is very important in the community service system. The pavement layer functions to receive traffic loads and spread it to the layer beneath it and then forward it to the subgrade. Based on the binding material, the pavement layer is divided into two categories, namely the flexible pavement layer and the rigid pavement layer. Flexible pavement is a road pavement that uses asphalt as a binding material for sand and split materials [1], [2], [3]. Rigid pavement is a road pavement that uses a concrete binder as the main structure and a surface wear layer, which is known as rigid pavement. The combination of these two types of pavement is called a composite pavement where the concrete structure is used as the substrate while the asphalt is used as the surface layer [4]-[10]. Planning refers to the AASTHO (American Association of State High and Transportation Officials) guide for design of pavement structures 2001. Practical steps/procedure steps and planning parameters are given as follows: Traffic analysis, including design life, average daily traffic average, annual traffic growth, vehicle damage factor, equivalent single axle load. Terminal serviceability index. Initial serviceability. Serviceability loss. reliability. Normal standard deviation. Standard deviation. CBR and subgrade reaction modulus. The modulus of elasticity of concrete, a function of the compressive strength of concrete. Flexural strength. Drainage coefficient. Load transfer coefficient. Rigid pavement is a structure consisting of one or several layers of pavement from processed materials, its function is to support the pavement of the selected material by supporting the weight of the traffic load without causing significant damage to the road. Rigid pavement structure consists of several layers with different hardness and soil bearing capacity, each layer of pavement must be guaranteed in its strength and thickness and not experiencing distress which means failure of construction planning. This research needs to be done because it looks at the conditions in the field and the existing research object needs to be handled as soon as possible. So that the damage is not getting worse so that road users are not hampered due to the condition of the road surface being heavily damaged. The planning carried out on the condition of Ciherang road and Pemuda road is to recalculate the rigid pavement to be applied to this road. The reason for choosing rigid pavement is based on the results of the sondir, the soil at the research location is a soil with an unstable sublayer, so rigid planning is needed. Rd

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Ciherang and Rd Pemuda, which are located in Dramaga District, Bogor Regency, are the connection between Dramaga Ring Road and Rd Dramaga Raya. The existing condition of the road is in the form of flexible pavement or asphalt, but there are several points that have been damaged. This is based on the amount of damage, both minor damage and major damage. Minor damage can be seen from the sand scattered on the road surface. Major damage is identified with the road surface being heavily damaged and there are moderate potholes and major damage at the observed points [11]-[17]. Damage is in the form of longitudinal cracking, cracks and holes/pothole. If left for a long time, it will worsen the condition of the existing pavement layer and also affect safety, comfort and smoothness in traffic, it is necessary to have an appropriate road improvement handling that can overcome the damage to the road so that the road can durable and to provide comfort and smooth operation for road users [18]-[24]. The geometric planning of the road is influenced by the contour of the land, the contour of the surrounding conditions, the foundation and the slope. So that it will be better to implement this planning through various tests and findings. The purpose of the test here is as a laboratory study material about the initial damage to surface conditions including the quality of the material used whether it is in accordance with technical specifications or not. The results of this test will be included in further studies to improve the quality of the materials used. The findings mean that the results of the damage found in the field, are severe damage from the side of the road being studied so that with this finding it is hoped that a good study will improve road conditions. One of these improvements is the design of rigid pavement to support the results obtained. The need for the test results and findings is to immediately find a solution to improve the condition of the potholes. It was found that the initial concept was planning for rigid pavement on the researched road section. This research is important to avoid further and repeated damage so that the road will be increasingly damaged, light and heavy vehicles are difficult to pass this path. The most appropriate step is to study planning in accordance with current conditions. This includes establishing a point of observation so that conditions in the field with heavy traffic, moderate traffic and low traffic [25]-[31]. This condition will be favorable in the initial assessment, so that the concept of a balanced master plan will make the planned road not experience difficult obstacles. These constraints will result in failed road planning. Heavy traffic will increase the level of road loads, increase the level of pollution and the level of the current condition of the road, as well as the life of the road [32]-[38]. The relationship between this research and the geometric road is the condition of the road at corners, especially extreme bends, so that the damage is the most dominant in this area. This condition triggers cracks on the road surface due to tire friction. Continuous friction will cause the road surface to wear out. The geometric condition of the road in the unstable aboveground sphere will also experience cracks. Especially with the vehicle load above normal. This vehicle load is exacerbated by the vehicle load exceeding the specified tonnage resulting in cracks on the road surface. This research is very important as a basis for the government of Bogor Regency to reorganize the damaged roads. The importance of rigid pavement planning as the main reason for the improvement of Ciherang and Pemuda roads needs further attention. So that the economy in the surrounding area runs smoothly and is not constrained by very severe road damage [42], [43].

MATERIAL AND METHOD

Time and place of research

Data collection was carried out for 2 days. This study took the location of Rd Ciherang and Rd Pemuda, Dramaga Subdistrict, Bogor Regency. The map of the location of research activities is shown in figure 1 below.

Figure 1: Research location (Source: Google map)

Material and Tools

The materials used in this research process are primary data which is surveyed directly to the research location and secondary data from related agencies. While the tools used are a push meter, office stationery, a numeric calculation tool/hand tally counter to calculate traffic data and a set of computers with AutoCAd Version 2010 [44] programs as a tool.

Research Flowchart

The following is a flowchart of the stages of the research which is outlined figure 2 below.

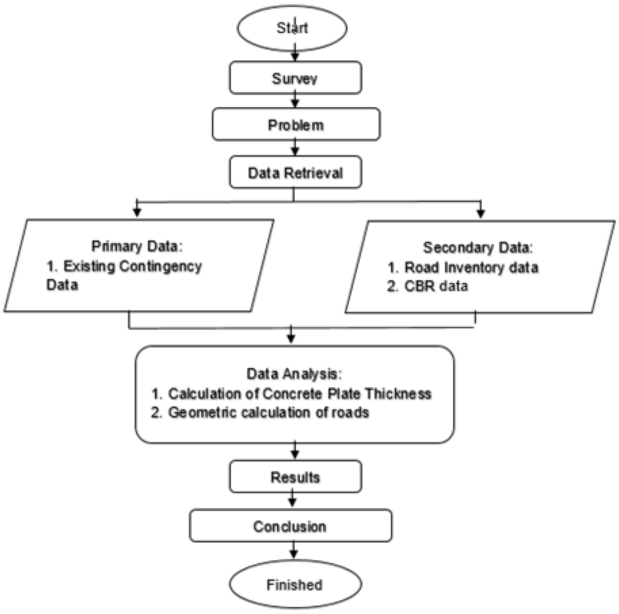

Figure 2: Research Flowchart

The explanation of Figure 2 of the methods and materials starts with the planning concept of rigid pavement thickness requiring data analysis and information as follows: Preparation stage This includes surveys, problems and basic data required are methods, materials and planning processes, determine data requirements, collect data on related institutions and data sources. Furthermore, data collection is carried out, namely soil CBR data, LHR data, choosing the type of rigid connected pavement and determining the road test class and determining the use of the road shoulder and concrete shoulder used. Data analysis with field observations and soil CBR data is determining the effective CBR based on the soil CBR value, determining the compressive strength of concrete and tensile strength of concrete reinforcement, determining the load safety factor according to road use and determining the distribution coefficient value according to the number of lanes based on the width of the pavement. Calculation of rigid pavement structure includes data analysis with pavement thickness with 90% effective soil CBR data, compressive strength of concrete or tensile strength of concrete reinforcement, determining the equivalent stress and erosion factor for the type of axis of each vehicle, determining the stress ratio factor by dividing the equivalent stress by flexural tensile strength, determine the load factor per wheel and multiplied by the load safety factor, calculate the stress ratio factor and the load per wheel, determine the number of repetitions permitted for erosion, then calculate the percentage of erosion repetitions planned to the number of permitted repetitions. Damage due to fatik and erosion is less than 100%. The data from the pavement calculation using the 2002 Bina Marga Method and the 2013 road pavement design manual were obtained and modeled in the form of a pavement layer image. Design of rigid compression design drawings using AutoCAD Version 2010 [44], [45].

RESULTS AND DISCUSSION

Existing conditions

Rd Ciherang and Rd Pemuda, Dramaga Subdistrict, Bogor Regency, are located in a densely populated area which connects in Rd Dramaga Raya and Dramaga Ring Road. The results of surveys and direct observations in the field of the existing conditions of the Rd Ciherang – Rd Pemuda already have flexible pavement or asphalt. However, there are several points of damaged road conditions that interfere with the comfort and safety of road users. The actual physical condition is shown in Figure 3 below.

Figure 3: Damage to Rd Ciherang and Rd Pemuda

Calculation and Design Results

Planning Parameter Data

The first step is to make observations in the field to get the thickness of the rigid concrete slab, using the Bina Marga Method [45]. Furthermore, the data obtained from the observations of Rd Ciherang - Rd Pemuda as shown in table 1 below.

Table 1: Observation data on Rd Ciherang - Rd Pemuda

No	Parameter	Value
1	Length of way	693 meters
2	Width of the road	7 meters
3	Street class	Collector
4	Number of paths	1
5	Number of lanes	2
6	Roadside	None

Steps to Calculate Plate Thickness

Traffic analysis

Based on the average daily traffic data, the calculation of the number of axes based on the type and load can be analyzed, as shown in table 2 below.

Number of commercial vehicle axes (JSKN) over the life of the plan (20 years).

JSKN = 365 x JSKNH x R

R $= \dfrac{(1+i)^{UR}-1}{i}$

$= \dfrac{(1+0{,}06)^{20}-1}{0{,}06}$

= 36,79

JSKN = 365 x 306 x 36,79

= 3.034.443

= 3.10 x 106

JSKNR = JSKN x C

= 3.10 x 106 x 1,00

= 3.10 x 106

Table 2: Calculation of the number of axes based on the type and load

Type Vehicle	Load Configuration Axis ton				Number of Vehicle	Number of Axes /Vehicle	Number of Axes (bh)	STRT		STRG		STdRG	
	RD	RB	RGD	RGB				BS (ton)	JS (ton)	BS (ton)	JS (ton)	BS (ton)	JS (ton)
(1)	(2)				(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Passenger Car	1	1	-	-	330	-	-	-	-	-	-	-	-
Pick up	1	1	-	-	62	-	-	-	-	-	-	-	-
Public Transportation	1	1	-	-	243	-	-	-	-	-	-	-	
Bus/Small Bus	3	5	-	-	22	2	44	3	22	5	22	-	-
Double Axis Light Truck	2	4	-	-	91	2	182	2 4	91 91	- -	- -	- -	- -
Total							226		204		22		-
Description: RD = Front Wheel, RB = Rear Wheel, RGD = Front Axle, RGB = Rear Trailer, BS = Axis Load, JS = Number of Axes, STRT = Single Axis Single Wheel, STRG = Single Axle for Double Wheel, STdRG = Double wheel tandem axis													

Table 3: Calculation of axis reps that occur

Type Axis	Load Axis (ton)	Amount Axis	Proportion Load	Proportion Axis	Traffic Plan	Reps what happened
(1)	(2)	(3)	(4)	(5)	(6)	(7) = (4)*(5)*(6)
STRT	2	91	0.45	0.40	3034440	545034
	3	22	0.11	0.10	3034440	31856
	4	91	0.45	0.40	3034440	545034
Total		204				
STRG	5	22	1.00	0.10	3034440	295338
Total		22				
Compulsive						1.417.311

Calculation of Axis Reps Occurring

Based on traffic data and Calculation of Number of Commercial Vehicle Axes according to Plan life (JSKNH), the next step is to calculate the axis reps that occur. The calculation of axis reps that occur is described in the table 3 below:

Calculation of Concrete Plate Thickness

Determination of concrete plate estimated thickness is obtained using graphic images from Bina Marga Method [45], as described in figure 4 below.

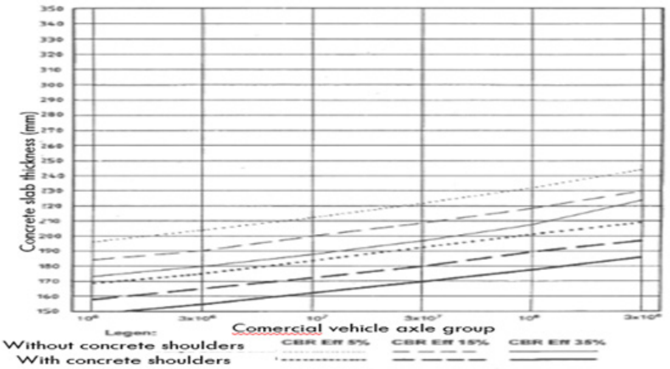

Figure 4: Example Planning Graph, fcf = 4.25 Mpa, Traffic – City Traffic, By Ruji, FKB = 1.1 (Source: Guidelines for Pavement of Bina Marga Cement Concrete Road 2002)

By determining the equivalent voltage (TE) and erosion factor (FE), it can be determined the voltage ratio factor (FRT) for each load plan per wheel such as table 4 below: The value for fatigue analysis and erosion is obtained using the graphic figure 5, figure 6, figure 7 and figure 8 below.

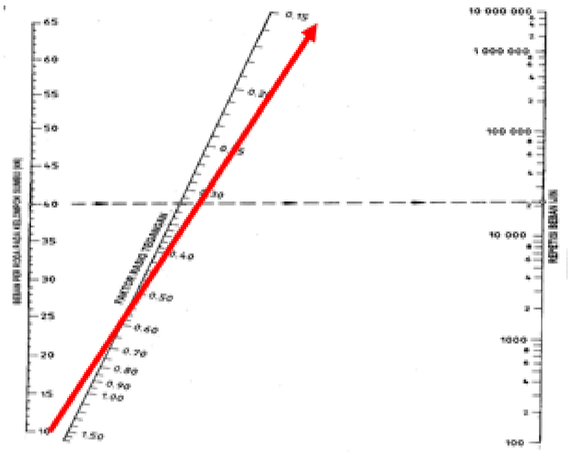

Figure 5: Fatik analysis and load permit based on voltage ratio, without concrete shoulder for STRT (2 ton)

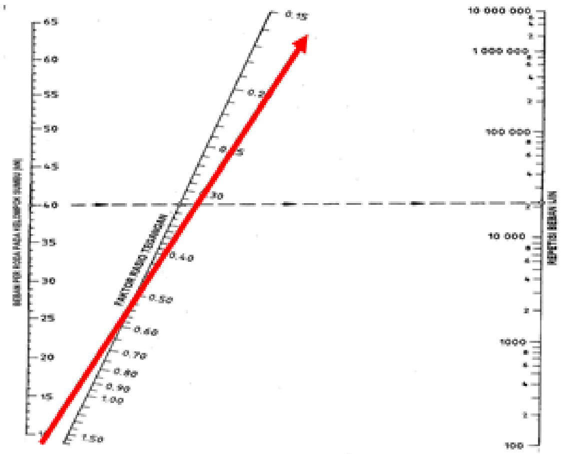

Figure 6: Fatik analysis and load permit based on voltage ratio, without concrete shoulder for STRT (3 ton)

Table 4: Fatik analysis and erosion analysis

Type Axis	Load Axis ton (kN)	Load Plan /Wheel (kN)	Reps That happen	Factor Voltage & Erosion	Fatik analysis		Erosion analysis	
					Reps Permit	Percent Damage (%)	Reps Permit	Percent Damage (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		=Axis Load /2*Fkb				=(4)*100/(6)		=(4)*100/(8)
STRT	2 (20) 3 (30) 4 (40)	10.00 15.00 20.00	545034 31856 545034	TE = 1.12 FRT = 0.30 FE = 2.34	TT TT TT	0 0 0	TT TT TT	0 0 0
STRG	5 (50)	12.50	295388	TE =1.76 FRT =0.48 FE = 2.94	TT	0	TT	0
Total					0% < 100%		0% < 100%	

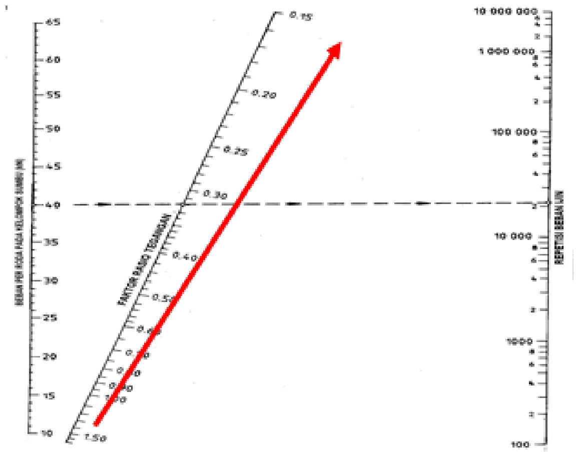

Figure 7: Fatik analysis and load permit based on voltage ratio, without concrete shoulder for STRT (4 ton)

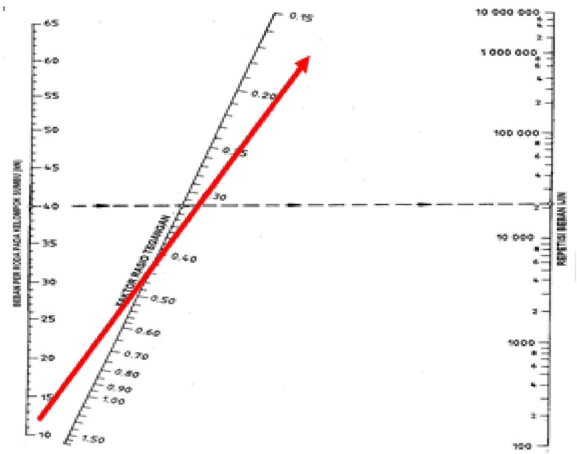

Figure 8: Fatik analysis and load permit based on voltage ratio, without concrete shoulder for STRT (5 ton)

From the data that has been done processing formed rigid pavement planning arrangement presented with the following figure 9 below.

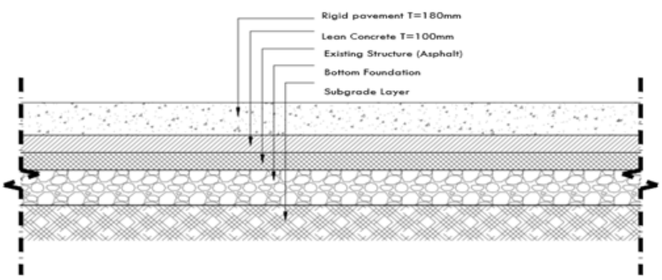

Figure 9: Rigid pavement design arrangement

Geometric Road Discussion Analysis

Geometric planning of Rd Ciherang and Rd Pemuda there are 5 (five) horizontal alignment bends that are reviewed with the following calculations:

Road Trase Calculation

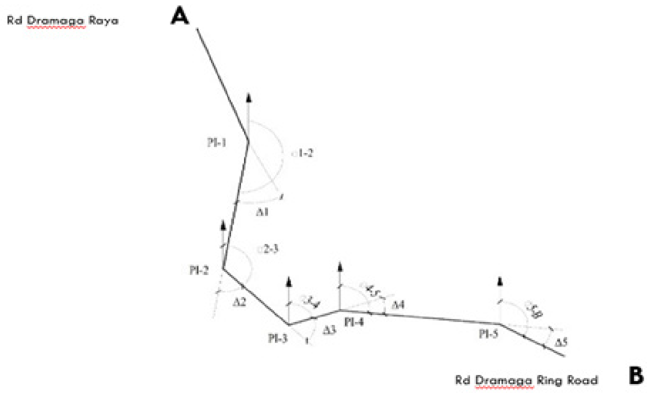

Figure 10: Image of road trase with azimuth angle graphic

Horizontal Alignment Calculation

Data and classification design:

Vr = 60 km/h

e_{max} = 10%

e_{normal} = 2%

Permeation Width (w) = 2x3.5m

Using the formula [39], [40]:

f_{max} = - 0.00065V + 0.192

= - 0.00065(60) + 0.192

= 0.153

$$D_{max} = \frac{181913,53\ (emax + fmax)}{Vr2}$$

$$= \frac{181913,53\ (0.1 + 0.153)}{60^2}$$

= 12,785°

$$R_{min} = \frac{60^2}{127\ (0.1 + 0.153)}$$

= 112m

1. PI-1 Bend

PI-1 bends are planned using SCS (Spiral-Circle-Spiral)

Δ1 = 29°36’25”

V_{plan} = 60 km/h

R_{min} = 112m

R_{plan} = 200m

Determining the super elevation of the design

D_{max} = 12.785°

$$D_{tjd} = \frac{1432,39}{200} = 7.162°$$

$$E_{tjd} = \{(-emax\ \frac{(Dtjd)2}{(Dmax)2} + 2\text{ x emax}\ \frac{(Dtjd)}{(Dmax)}$$

$$= \{(-0{,}10\ \frac{(7.162)2}{(12.785)2}) + (2 \text{ x } 0.10\ \frac{(7{,}162)}{(12{,}785)}$$

= 0.080

= 8%

Determine the value of the transition curve length (L_{smin})

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

$$Ls\ = \frac{Vr}{3.6} \text{ x T} = \frac{60}{3.6} \text{ x } 3 = 50\text{m}$$

Based on Shortt's modification formula:

$$Ls\ = 0.022 \text{ x} \frac{Vr3}{Rr \text{ x } C} - 2{,}727 \frac{Vr \text{ x etjd}}{C}$$

$$Ls\ = 0.022 \text{ x} \frac{60^3}{200 \text{ x } 0{,}4} - 2.727 \frac{60 \text{ x } 0.080}{0{,}4} = 26.67\text{m}$$

Based on the level of achievement of changes in reliability:

$$Ls\ = \frac{(em - en)}{3.6 \text{ x } re} \text{ x Vr}$$

Where re = achievement level changes in the radius of the road, for Vr ≤ 70 km/h, re_{max} = 0.035 m/(m/det).

$$Ls\ = \frac{(0{,}1 - 0{,}02)}{3.6 \text{ x } 0.035} \text{ x } 60 = 38.095\text{m}$$

Used the largest Ls value is 50m. Calculation Ɵs, Δc, and Lc

$$\theta s\ = \frac{90}{\pi} \text{ x} \frac{Ls}{Rr}$$

$$= \frac{90}{3{,}14} \text{ x} \frac{50}{200} = 7°9'43"$$

$$\Delta c\ = 29°36'25" - (2\text{x}7°9'43")\ =\ 15°16'59"$$

$$Lc\ = \frac{\Delta c \text{ x } \pi \text{ x Rr}}{180}$$

$$= \frac{15°16'59" \text{ x } \pi \text{ x } 200}{180} = 53.35\text{m}$$

S-C-S bend requirements

Lc > 20

53.35 m > 20m. (OK).

Then the bend S – C – S can be used. Calculation of the magnitude of the bend

$$Xs = Ls \left(1 - \frac{Ls^2}{40 \text{ x } Rr^2}\right)$$

$$= 50 \left(1 - \frac{50^2}{40 \text{ x } 200^2}\right) = 40.438\text{m}$$

$$Ys = \frac{Ls^2}{6 \text{ x } Rr}$$

$$= \frac{50^2}{6 \text{ x } 200} = 2.08\text{m}$$

$$P = Ys - [Rr(1 - \cos \theta s]$$

$$= 2{,}08 - [200(1 - \cos 7°9'43"] = 0.51\text{m}$$

$$K = Ls - \left(\frac{Ls^2}{40 \text{ x } Rr^2}\right) - (Rr \text{ x } sin\ \theta s)$$

$$= 50 - \left(\frac{50^2}{40 \text{ x } 200^2}\right) - (200 \text{ x } sin\ 7°9'43"")$$

$$=\ 25.06\text{m}$$

$$Tt = (Rr + P\ ) \text{ x Tan} \frac{1}{2} \Delta 1 +\ K$$

$$Tt = (200 + 0.51\ ) \text{ x Tan} \frac{1}{2} 29°36'25" +\ 25.06$$

$$= 78.05\text{m}$$

$$Et = \left(\frac{Rr + P}{\cos \frac{1}{2} \Delta 1}\right) - Rr$$

$$= \left(\frac{200 + 0.51}{\cos \frac{1}{2} 29°36'25"}\right) - 200 = 7.39\text{m}$$

$$\text{Ltotal}\ = Lc + (2 \text{ x } Ls) = 53.35 + (2\ x\ 50) = 153.35\text{m}$$

2 x Tt > L_{total}

2 x 78.05 m > 153.35m

156.1 m > 153.35m (OK).

Then the bend S-C-S can be used.

The results of calculation of PI-1 bends of spiral-circle-spiral type (SCS) are shown in table 5 below.

Table 5: PI-1 bend calculation result of spiral-circle-spiral (SCS)

Value	
R	200
Δ1	29°36'25"
Ls	50m
Ɵs	7°9'43"
Xs	40.438m
Ys	2.08m
K	25.06m
p	0.51m
Ts	78.05m
Es	7.39m
Δc	15°16'59"
Lc	53.35m
Lt	153.35m

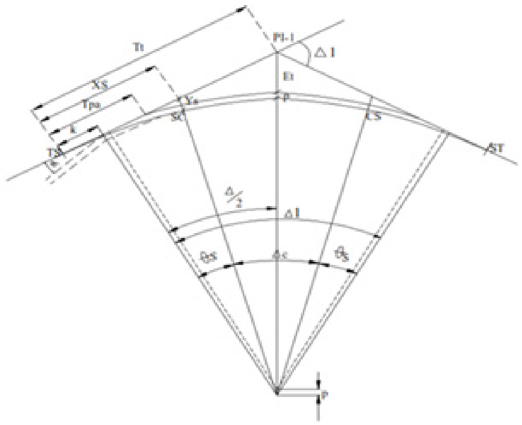

Figure 11: PI-1 Bend

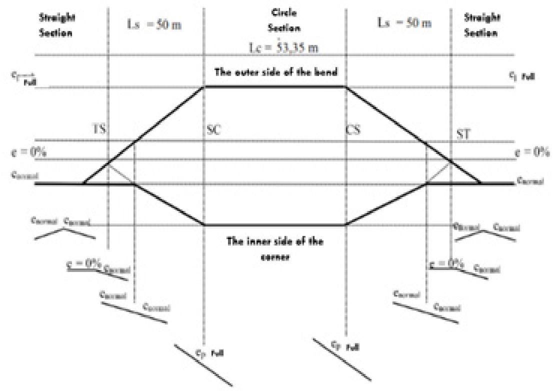

Figure 12: Spiral Type PI–1 bend super elevation Circle – Spiral

2. PI-2 Bend

PI-2 bends are planned using SCS (Spiral-Circle-Spiral)

Δ2 = 52°29'6"

V_{plan} = 60 km/h

R_{min} = 112m

R_{plan} = 200m

Determining the super elevation of the design

D_{max} = 12,785°

$$D_{tjd} = \frac{1432,39}{200} = 7.162°$$

$$E_{tjd} = \{(-emax\ \frac{(Dtjd)2}{(Dmax)2} + (2 \text{ x emax } \frac{(Dtjd)}{(Dmax)}$$

$$= \{(-0.10\ \frac{(7,162)2}{(12,785)2} + (2 \text{ x } 0.10\ \frac{(7,162)}{(12,785)}$$

= 0.080

= 8%

Determine the value of the transition curve length ($_{Lsmin}$)

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

$$Ls = \frac{Vr}{3.6} \text{ x T} = \frac{60}{3.6} \text{ x } 3 = 50\text{m}$$

Based on Shortt's modification formula:

$$Ls = 0,022 \text{ x} \frac{Vr3}{Rr \text{ x } C} - 2,727 \frac{Vr \text{ x etjd}}{C}$$

$$Ls = 0.022 \text{ x} \frac{60^3}{200 \text{ x } 0.4} - 2,727 \frac{60 \text{ x } 0.080}{0.4} = 26.67\text{m}$$

Based on the level of achievement of changes in reliability:

$$Ls = \frac{(em - en)}{3.6 \text{ x } re} \text{ x Vr}$$

Where re = achievement level changes in the radius of the road, for Vr ≤ 70 km/h, re_{max} = 0.035 m/(m/det).

$$Ls = \frac{(0,1 - 0.02)}{3.6 \text{ x } 0.035} \text{ x } 60 = 38.095\text{m}$$

Used the largest Ls value is 50m. Calculation ϴs, Δc, and Lc

$$ϴs = \frac{90}{\pi} \text{ x} \frac{Ls}{Rr}$$

$$= \frac{90}{3,14} \text{ x} \frac{50}{200} = 7°9'43"$$

$$Δc = 52°29'6" - (2x7°9'43") = 38°9'40"$$

$$Lc = \frac{Δc \text{ x } \pi \text{ x Rr}}{180}$$

$$= \frac{38°9'40" \text{ x } \pi \text{ x } 200}{180} = 133.21\text{m}$$

S-C-S bend requirements

Lc > 20

133.21m > 20m. (OK).

Then the bend S – C – S can be used.

Calculation of the magnitude of the bend

$$Xs = Ls \left(1 - \frac{Ls^2}{40 \text{ x } Rr^2}\right)$$

$$= 50 \left(1 - \frac{50^2}{40 \text{ x } 200^2}\right) = 40.438\text{m}$$

$$Ys = \frac{Ls^2}{6 \text{ x } Rr}$$

$$= \frac{50^2}{6 \text{ x } 200} = 2.08\text{m}$$

$$P = Ys - [Rr(1 - \cos ϴs]$$

$$= 2,08 - [200(1 - \cos 7°9'43"] = 0.51\text{m}$$

$$K = Ls - \left(\frac{Ls^2}{40 \text{ x } Rr^2}\right) - (Rr \text{ x } sin\ ϴs)$$

$$= 50 - \left(\frac{50^2}{40 \text{ x } 200^2}\right) - (200 \text{ x } sin\ 7°9'43"")$$

$$= 25.06\text{m}$$

$$Tt = (Rr + P) \text{x Tan} \frac{1}{2} Δ2 + K$$

$$Tt = (200 + 0{,}51)\,x\, Tan \frac{1}{2} 52°29'6" + 25{,}06$$

$$= 123.91m$$

$$Et = \left(\frac{Rr + P}{\cos\frac{1}{2}\Delta 2}\right) - Rr$$

$$= \left(\frac{200 + 0{,}51}{\cos\frac{1}{2} 52°29'6"}\right) - 200 = 23.55m$$

$$Ltotal = Lc + (2\,x\,Ls) = 133{,}21 + (2\,x\,50)$$

$$= 233.21m$$

2 x Tt > Ltotal

2 x 123.91m > 233.21m

247.82m > 233.21m. (OK).

Then the bend S-C-S can be used.

The results of calculation of PI-2 bends of spiral-circle-spiral type (SCS) are shown in table 6 below.

Table 6: PI-2 bend calculation result of spiral-circle-spiral type (SCS)

Value	
R	200
Δ1	52°29'6"
Ls	50m
Ɵs	7°9'43"
Xs	40.438m
Ys	2.08m
K	25.06m
p	0.51m
Ts	123.91m
Es	23.55m
Δc	38°9'40"
Lc	133.21m
Lt	233.21m

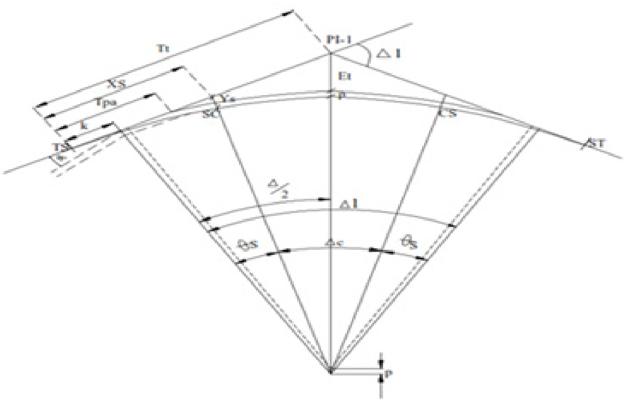

Figure 13: PI-2 Bend

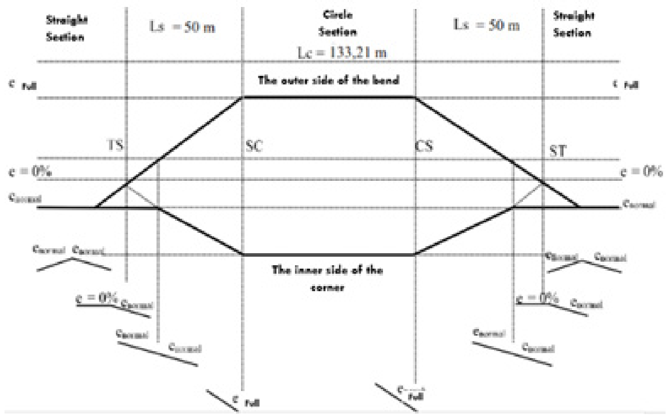

Figure 14: Spiral Type PI–1 bend super elevation diagram Spiral - Circle – Spiral

3. PI-3 Bend

PI-3 bend planned using FC (Full-Circle)

Δ3 = 66°32'5"

V_{plan} = 60 km/h

R_{min} = 112m

R_{plan} = 150m

e = 9.3 %

Calculation of the magnitude of the bend

$$Tc = Rr\,x\,Tan\frac{1}{2}\Delta 3$$

$$= 150\,x\,Tan\frac{1}{2}\,x\,66°32'5" = 98.41m$$

$$Ec = Tc\,x\,Tan\frac{1}{4}\Delta 3$$

$$= 98.41\,x\,Tan\frac{1}{4}\,x\,66°32'5" = 29.40m$$

$$Lc = \frac{\Delta 3\,x\,2\,\pi\,x\,Rr}{360°}$$

$$= \frac{66°32'5"\,x\,2\,\pi\,x\,150}{360°} = 174.19m$$

Full Circle bend requirements

Lt = Lc =174.19m

2Tc > Lc

(2 x 98.41) > 174.19

196.82m > 174.19m. (OK).

Full Circle bends can be used.

The results of the calculation of PI-3 bends of Full Circle (FC) type are shown in table 7 below.

Table 7: Full Circle (FC) PI-3 bend calculation results

Value	
R	150
Δ3	66°32'5"
Tc	98.41m
Ec	24.00m
Lc	174.19m

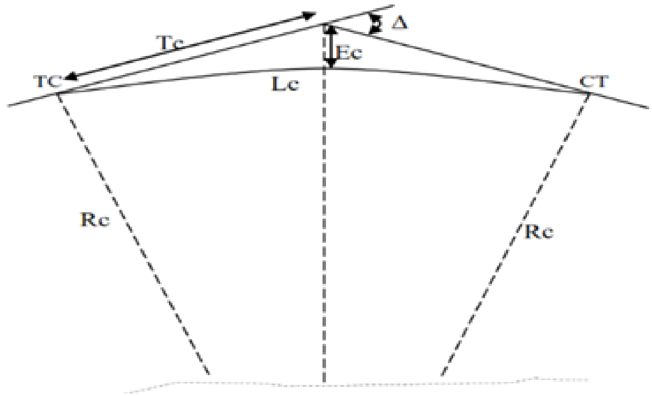

Figure 16: PI-3 Bend

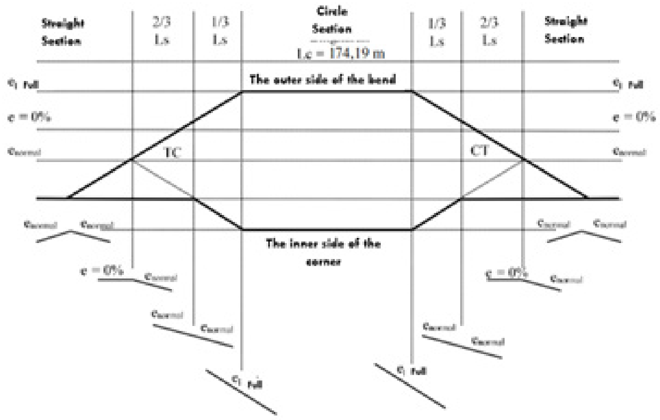

Figure 17: Full Circle Pi–3 bend super elevation diagram

4. PI-4 Bend

PI-4 bend planned using FC (Full-Circle)

$\Delta 4$ = 26°1'5"

V_{plan} = 60 km/h

R_{min} = 112m

R_{plan} = 150m

e = 9.3 %

Calculation of the magnitude of the bend

$$Tc = Rr \text{ x } Tan \frac{1}{2} \Delta 4$$

$$= 150 \text{ x } Tan \frac{1}{2} \text{ x } 26°1'5" = 34.65m$$

$$Ec = Tc \text{ x } Tan \frac{1}{4} \Delta 4$$

$$= 34{,}65 \text{ x } Tan \frac{1}{4} \text{ x } 26°1'5" = 3.95m$$

$$Lc = \frac{\Delta 4 \text{ x } 2 \,\pi \text{ x } Rr}{360°}$$

$$= \frac{26°1'5" \text{ x } 2 \,\pi \text{ x } 150}{360°} = 68{,}11m$$

Full Circle bend requirements

Lt = Lc = 68.11m

2Tc > Lc

(2 x 34.65) > 68.11

69.3m > 68.11m. (OK).

Full Circle bends can be used.

The results of the calculation of PI-4 bends of Full Circle (FC) type are shown in table 8 below.

Table 8: Full Circle (FC) PI-4 bend calculation results

Value	
R	150
Δ4	26°1'5"
Tc	34.65m
Ec	3.95m
Lc	68.11m

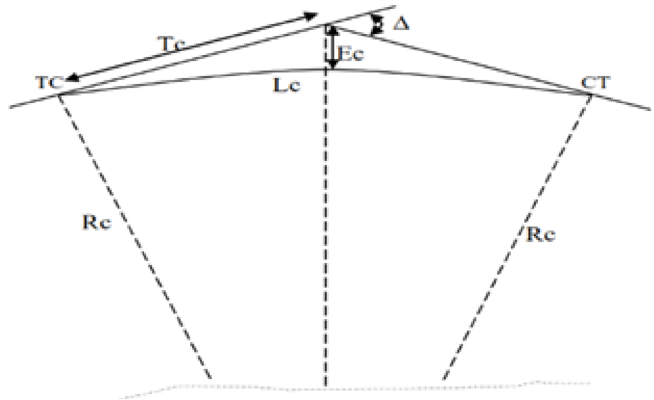

Figure 18: PI-4 Bend

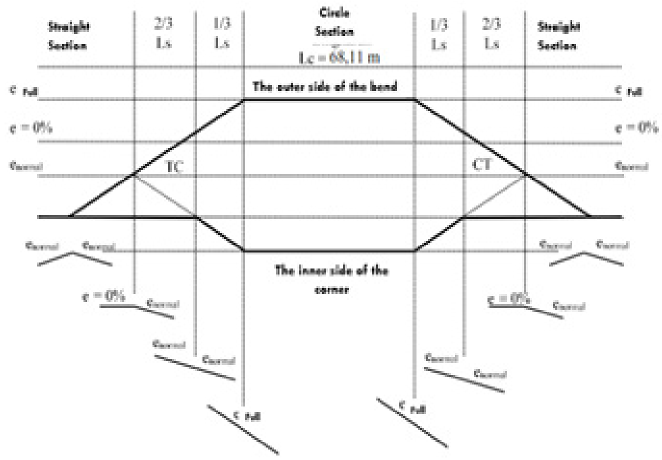

Figure 19: Full Circle PI–4 Bend Super elevation Diagram

5. PI-5 Bend

PI-5 bend planned using FC (Full-Circle)

$\Delta 5$ = 25°23'18"

V_{plan} = 60 km/h

R_{min} = 112m

R_{plan} = 150m

e = 9.3 %

Calculation of the magnitude of the bend

$$\mathrm{Tc} = \mathrm{Rr} \times \mathrm{Tan}\,\frac{1}{2}\Delta 5$$

$$= 150 \times \mathrm{Tan}\,\frac{1}{2} \times 25°23'18'' = 33.78\text{m}$$

$$\mathrm{Ec} = \mathrm{Tc} \times \mathrm{Tan}\,\frac{1}{4}\Delta 5$$

$$= 33{,}78 \times \mathrm{Tan}\,\frac{1}{4} \times 25°23'18'' = 3.75\text{m}$$

$$\mathrm{Lc} = \frac{\Delta 5 \times 2\,\pi \times \mathrm{Rr}}{360°}$$

$$= \frac{26°1'5'' \times 2\,\pi \times 150}{360°} = 66.47\text{m}$$

Full Circle bend requirements

Lt = Lc = 66.47m

2Tc > Lc

(2 x 33.78) > 66.47

67.56m > 66.47m. (OK).

Full Circle bends can be used [1], [3], [7], [41].

The results of the calculation of PI-5 bends of Full Circle (FC) type are shown in table 9 below.

Table 9. Full Circle (FC) PI-5 bend calculation results

Value	
R	150
Δ4	25°23’18”
Tc	33,78m
Ec	3.75m
Lc	66.47m

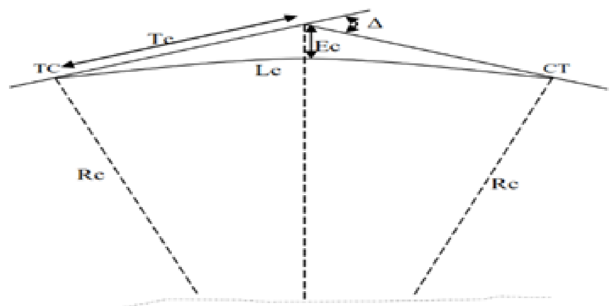

Figure 20: PI-5 Bend

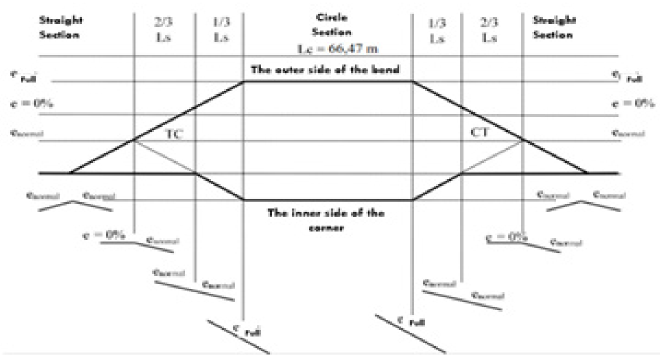

Figure 21: Full Circle PI–5 bend super elevation diagram

CONCLUSION

The existing condition of the road in the form of flexible pavement with asphalt, there are several points that have been damaged. Damage in the form of longitudinal cracks and holes. It is necessary to improve the handling of the road to provide smooth, comfortable for road users by means of additional coating of rigid pavement on top of the asphalt layer. The rigid pavement is designed for one lane and two directions with a design life of 20 years of continuous concrete compression. The bottom foundation uses K-125 lean concrete mixture with a thickness of 10cm. Determination of the estimated thickness of the concrete slab is obtained using a graphic image from the 2002 Bina Marga method. The estimated thickness of the concrete slab is 18cm with a concrete quality of K-350. Reinforcement for dowels uses iron with a diameter of 25mm, a length of 450mm and a distance of 300mm. Longitudinal connection using iron diameter 16mm, length 700mm and distance 600mm. Geometric planning Rd. Ciherang - Rd. Pemuda there are five forms of horizontal alignment bend. The PI-1 bend is planned to use SCS (Spiral-Circle-Spiral) with a bend length of 153.35m. The PI-2 bend is planned to use SCS (Spiral-Circle-Spiral) with a bend length of 233.21m. The PI-3 bend is planned to use FC (Full Circle) with a bend length of 174.19m. The PI-4 bend is planned to use FC (Full Circle) with a bend length of 68.11m. The PI-5 bend is planned to use FC (Full Circle) with a bend length of 66.47m. There is no incline found so that there is no vertical alignment planning.

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