PLANNING THE PASURUAN–PROBOLINGGO SECTION IV-A TOLL ROAD (CLARAK STA 31+300 TO PENDIL STA 39+875)

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ABSTRACT

Probolinggo has considerable tourism potential. This has an impact on economic growth in Probolinggo. With the increasing need for vehicles, the capacity of the road will also increase. To overcome these problems, the government is increasing road capacity by building expressways (Toll Roads). The Pasuruan-Probolinggo expressway (Tol) section IV was built to cope with the increasing traffic volume every year. The Pasuruan-Probolinggo Toll Road is also a program from the government to overcome congestion on the main arterial road Pasuruan-Probolinggo. In this discussion, it will be explained about the planning of the Pasuruan-Probolinggo toll road section IV which connects Leces District with Gending which will be assisted by AutoCad Civil 3D software.To plan geometrically, the author refers to the guidelines of the Highway Regulation for Geometric Planning of Freeways No.007/BM/2009 and for road pavement planning using the Manual Guidelines for Road Pavement Design No.04/SE/Db/2017. Drainage planning refers to regulation Pd-T-2-2006-B, for the calculation of the Cost Budget Plan using the 2023 Probolinggo City Unit Price Standard and Price Analysis Unit Work Unit. From the results of this road design, the number of horizontal curves is 6 curves and 22 vertical curves. The pavement uses flexible pavement with a thickness of AC-WC 40 mm, AC-BC 60 mm, AC-Base 100 mm, CTB 150 mm, LFA Class A 150 mm. Drainage is planned in the form of a trapezium made of concrete with 3 different sizes for side channels and 3 different sizes for culverts, the total cost of the plan design reaches Rp. 262,508,286,380.00 (Two hundred and sixty-two billion five hundred eight million two hundred eighty-six thousand three hundred and ten rupiah)

INTRODUCTION

Probolinggo is one of the regencies in East Java province that has a large tourism potential so that it has an impact on its increasing economic growth which causes an increase in the need for the number of vehicles. Traffic jams will occur due to the large volume of traffic vehicles passing through the road. To overcome these problems, the government is increasing road capacity by building toll roads. The Pasuruan-Probolinggo Toll Road is one of the Trans Java Toll Roads which is a program from the Government that connects cities in East Java which is expected to reduce congestion on the Pasuruan-Probolinggo road.

Software that makes it easier to calculate designs in the construction field is BIM (Building Information Modelling) [1]. One of the BIMs that can be used for highway planning is AutoCad Civil 3D which can be used for design and design analysis of various types of civil infrastructure buildings, one example is highways [2].

This journal will discuss the geometric planning of the Pasuruan - Probolinggo Toll Road Section IV-A which connects Clarak and Pendil with the help of AutoCad Civil 3D software, which is expected to produce geometry with the help of BIM (Building Information Modelling) to produce geometrics that suit the needs.

LITERATURE REVIEW

A. *Traffic Capacity Analysis*

Traffic capacity analysis is used to plan the amount of vehicular traffic passing through the road. In road Geometric planning, traffic analysis is very necessary and influential because it is used to determine the segments of a road.

B. *Road Traffic Characteristics*

Traffic data is the main data needed for road planning because the capacity of the road to be planned depends on the composition of traffic that will use the road on a segment of road to be reviewed.

In determining road characteristics, the vehicle will

Table 1 Capacity of 4-lane 2-way freeway

JBH Type/Lineage type	Basic Capacity (skr/hour/lane)
JBH 4/2 and JBH 6/2	
Flat	2300
Hill	2250
Mountain	2150

Source: Indonesia Road Capacity Guidelines 2014 Freeways

determine the load class or MST (Heaviest Axis Load) that affects pavement planning. Analysis of traffic data is carried out to determine road capacity but must be done in conjunction with road Geometric planning and others.

C. Horizontal Alignment Planning

Horizontal alignment is the projection of the road axis on the horizontal plane of the road map [3]. The road alignment consists of a straight section and a curved section (bends). Geometric planning on curved sections is intended to compensate for the centrifugal force received by a vehicle traveling at a certain speed. For bend planning, efforts are made to provide safety and comfort.

D. *Vertical Alignment Planning*

Vertical alignment is a vertical projection on a roadmap. From the vertical elevation, it can be known the ground elevation on the road [3]. The vertical alignment consists of two parts, namely the straight part and the curved part. Judging from the starting point planning, the straight section can be either positive ramps (climbs), or negative ramps (descents), or zero ramps (flat). The vertical curved part can be either a concave arch or a convex arch.

E. Pavement Planning

Road pavement is part of the traffic lane, where structurally in the cross section of the road, is the cross-section of the structure in the most central position in a road body whose purpose is to be able to channel the load of passing vehicles above the road surface. Road Pavement Design is planned to use bending pavement with reference to Highways on the Road Pavement Design Manual in 2017.

F. Drainage Channel Planning

1) General Pattern of Drainage System

Highway drainage systems generally follow river flow patterns. The area affected by rainwater then flows into the roadside channel until it ends at a lake or sea. The road surface is also made to have a slope that aims to allow rainwater falling on the road surface to immediately flow into the roadside channel, so that it does not pool on the road surface.

2) Highway Drainage

Drainage is an important facility because it is designed and designed so that water can flow properly and so that water does not stagnate. Where water will be discharged or flowed naturally or artificially from the surface or subsurface of a place. This disposal can be done by draining, draining, discarding, or diverting water.

3) Hydrological Analysis

This analysis is used to determine the flow of water flowing on the planned road according to the age of the plan. To calculate the flow discharge on the road this plan includes concentration time (tc), rain intensity (I), flow coefficient (C), hydrological discharge calculation (Qhydrology).

4) Hydraulics Analysis

Hydraulics analysis is carried out to determine the discharge of water flow flowing in the planned channel according to the age of the road plan. Parameters for calculating flow discharge in drainage channels include the circumference of the Wet Channel (P), the area of the Wet Cross Section (A), the slope of the Transverse channel (I), and the calculation of Hydraulic Discharge (Qhidroulca).

5) Culvert Dimension Planning

A culvert is a channel placed across the road that serves to collect water from the upper reaches of the drainage channel and drain it. In planning the dimensions of the culvert, the thing that needs to be considered is the flow discharge, the flow discharge is obtained from the side channel discharge before or after the culvert.

G. AutoCAD Civil 3D

Civil 3D is one *Software* which includes BIM circles [1]. The use of Civil 3D for geometric road design is by inputting contour data, then determining the start and end points of the road that will begin to be designed by making alternative trace, trace drawing must start from the starting point of the road plan, this aims to determine STA that makes it easier to analyze further, such as horizontal, vertical, and excavation and stockpiles.

METHODOLOGY

A. Data Collection

In planning the Pasuruan-Probolinggo Toll Road, technical data is needed that can be obtained from related agencies, for example from the Owner, Consultant or Contractor. Technical data needed as a reference include:

1 Secondary Data:

a. Topographic measurements are a factor in determining the location of roads and generally affect the determination of road trace, such as: road ramps, visibility, cross section, and others. Hills, valleys, rivers, and lakes often place restrictions on location and planning on road traffic.
b. The volume of traffic used to understand the planned road capacity depends on the composition of traffic that will use the road on a segment of road under review.
c. Rainfall data for drainage system planning.
d. The unit price of activities is obtained from the HSPK of East Java Province in 2023. HSPK is used as a reference cost for materials and labor, as well as the National average cost for RAB planning.

2 Primary Data:

a. Highways Regulation No.007/BM/2009 is used as a reference for geometric road planning covering all existing aspects.
b. Toll Road Design Criteria are used to determine the maximum and minimum limits of geometric planning of toll roads (freeway).
c. Highways Regulation No. 04/SE/Db/2017 Road Pavement Manual as a reference for road

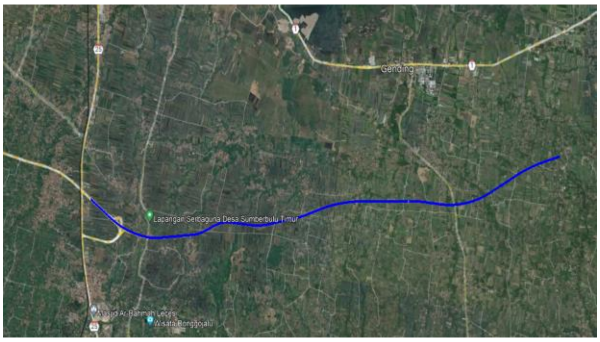

Figure 1 Trase *Images*

pavement.

d. Road Drainage System Planning Pd. T-02-2006-B as a reference for drainage channel planning.

B. Data Processing and Analysis Techniques

The data that has been obtained is processed using Microsoft Excel. The processing carried out includes trace design referring to contour maps and rainfall data. Furthermore, the planning process is carried out using AutoCAD which results in knowing horizontal alignment, vertical alignment, cross section of the road, superelevation diagram.

1) Contour Map

Contour maps show the state of the earth's surface such as altitude, which serves as material in planning a trace.

2) Traffic Volume

Traffic volume data is used as a reference in road geometric planning, i.e. for road pavement design.

3) Rainfall Data

The rainfall data itself is used to design the drainage canal to be planned.

4) HSPK

HSPK data is used to calculate material budget plans costs on planned designs.

C. Planning Calculation

After a complete literature and data study, the next step is to determine the status of the road including the type of road and road class which will be used to determine the speed of the plan, the speed of the plan itself is used in geometric planning, namely horizontal and vertical alignment.

1) Horizontal Alignment Planning

The planning is assisted by AutoCAD Civil 3D software which is controlled by the Geometric Highway Guideline Regulation No. 007 / BM / 2009 of the Department of Public Works Directorate General of Highways in 2009

2) Vertical Alignment Planning

The planning is also assisted by AutoCAD Civil 3D software which is controlled by the regulation of Geometric Guidelines for Freeway No.007 / BM / 2009 of the Department of Public Works Directorate General of Highways in 2009

3) Depiction of Long Section and Cross Section

This depiction is done using the help of AutoCAD Civil 3D software and perfected using *AutoCAD* software.

Table 2 Design Trase Data

No	Element	Value (m)
1	Trase length	8575,000 m
2	Longest straight section length	1347.260 m
3	Number of bends	6 pcs
4	Highest Agility	5 %
5	Lowest slope	0 %
6	Total average agility	0.87 %

Table 3 Comparison of Existing Trase with Plan

No	Element	Alt	Existing
		Value	Value (m)
1	Trase length	8575,000 m	8775 m
2	Longest straight section length	1347.260 m	1497 m
3	Number of bends	6 pcs	6 pcs
4	Highest Agility	5 %	5 %
5	Lowest slope	0 %	0 %
6	Average agility	0.87 %	1 %

4) Volume cut and fill calculation.

Calculation of cut and fill volume using the help of AutoCAD Civil 3D software from the results of geometric designs that have been done.

5) Pavement Thick Planning

The guidelines in pavement design refer to the 2017 Pavement Design Manual

6) Drainage Channel Planning

Drainage channel planning includes the design of edge channels and culvert channels with guidelines on regulations (PD-T-02-2006-B).

7) Implementation Method

The implementation method focuses on earthworks, starting from land preparation to excavation and stockpiling work so that a project site / area is formed that is ready for further work.

8) Calculation of Cost Budget Plan (RAB)

This calculation is aimed at finding out the costs required in the road construction work of the plan, which includes materials, and labor wages.

D. Planning Results

The planning results on the geometric alternative design of Pasuruan – Probolinggo Section IV Toll Road are as follows:

1. Road Trase Design
2. Horizontal and Vertical Alignment Design
3. Long section and cross section images
4. Pavement Thickness Design
5. Drainage Channels, including side channels and culverts.
6. Volume of Work
7. Methods of Execution of Work
8. RAB

RESULTS AND DISCUSSION

A. Trase Planning

In planning a trace, there are several factors to consider, namely the length of the trace, the length of the longest straight section, the number of bends, the highest slope, the lowest slope, and the total average slope. The

Table 4 Technical design criteria

No	Elements of technical design criteria		Criterion Value
1	VD, Km/h		120
2	Grademax, %		10
3	Greatest transverse stiffness (fmax)		0.092
4	Greatest superelevation (emax), %		8
5	Rmin horizontal arch, m		659
6	Lmin vertical curve, m, or K value		120m or Convex >26 Concave >30
7	The longest straight section length, m		1347.26
8	Road type and road dimensions	Road type	4/2 S
		Lane width, m	3.6
		Shoulder width, m	3
		Verge width, m	1.5
9	Transverse slope	Road lanes, %	3
		Shoulder, %	5
10	Street space	Rumaja, m	30
		Rumija, m	40
		Ruwasja, m	75
11	Total length, m		8575
12	Number of bends		6

Table 5 LHR Data Pasuruan-Probolinggo Road

Plan Year	SEDAN, JEEP, ST, WAGON	Small public transport	Medium bus	Big buses	Small bus pass	2-axle small truck	2 axle medium truck	3 axle truck	4 axle truck	≥5-axle truck	Total vehicles	Direction of Travel
2020	3271	75	14	267	680	955	373	284	142	70	6131	Pasuruan - Probolinggo
	3230	75	14	264	671	943	368	280	140	69	6053	Probolinggo - Pasuruan
	6501	150	28	531	1351	1897	741	564	281	140	12184	Total dua arah

Source: PT. Virama Karya Konsultan

Table 6 Daily Traffic Volume Recapitulation

Ket.	LHR 2023
Sedan, Jeep, and Station wagon	3355
Small Public Transport	77
Medium Bus	14
Big Bus	274
Small Box Delivery	697
Small Truck 2 Axles	979
2 Axle Medium Truck	383
3 Axle Truck	291
4 Axle Truck	146
>5Axle Truck	72
Total Vehicles	6288

traffic plan that will be used is not much different from the existing trace, it's just that here the author plans a direct design of data input on AutoCAD Civil 3D.

1) Design Trase Condition Analysis

From several factors that affect the trace above, it is necessary to analyze the condition of the trace to make an assessment in accordance with predetermined criteria.

The trace is designed with the aim of minimizing the height difference that occurs, therefore producing a trace channel with a length of 8.575 km with 6 beds and passing through 13 rivers, for clearer specifications will be shown in Table.

2) Comparison of Plan Design with Existing

Here is a comparison of existing and planned traces where there are only a few slight differences for the trace made. From the comparison of the trace, the alternative length is 8,575 because it only takes Section IV-A while for *existing* 12,575 with Sections IV-A and IV-B and 8775 for section IV-A only. The difference in the length of the straight section is 149.74 m over the length of the existing trace.

B. Road Geometric Planning Data

It is planned that the road has a role to connect between cities that have the status of toll roads and have a function as a class 1 primary artery, flat road terrain conditions, therefore it has a planned speed of 120 based on road geometric design guidelines [3].

Table 4 represents the technical design criteria for alternative design references, which include plan velocity values (V_D), *emax grade*, greatest transverse stiffness, greatest superelevation, minimum horizontal curvilinear radius, minimum vertical curvilinear length and also K values, longest straight section length, road type and design road dimensions, transverse road slope, road space, total length of design road, and the number of bends.

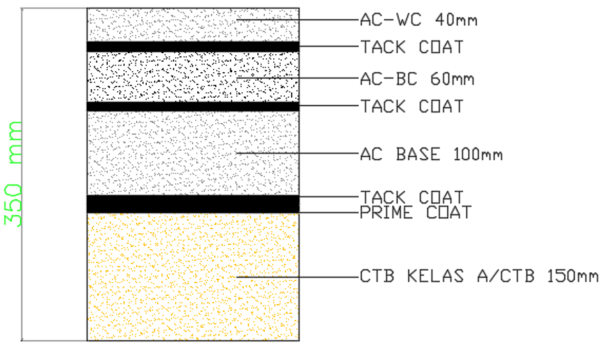

Figure 2. *Pavement Thick Layer Plan*

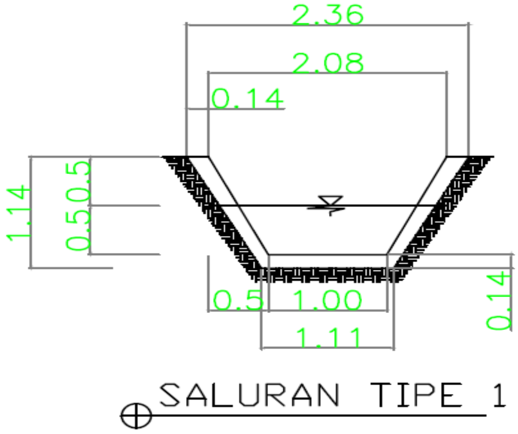

Figure 3. *Channel Type 1*

C. *Horizontal Alignment Planning*

This alternative design horizontal arrangement planning uses *Spiral-Circle-Spiral (S-C-S), Full Circle (FC),* and *Spiral-Spiral (SS) types.* The use of the S-C-S curve aims to avoid sudden changes in slope, while for the use of FC and SS to follow the road terrain.

Based on Table 4, the permissible length of the straight section with a plan speed (VD) of 120 km/h is 5000 m. At the azimuth angle of the starting point to PI (P1) the location of the PI lin is obtained in Quadrant II which will later be added by. while the results of azimuth angles at points P1 to P2 obtained the location of the PI line are in Quadrant I.180°

Based on the determination of the planned bend radius (Rc) from the minimum bend radius obtained, it is planned (Rc) of 660 m. The minimum transition curvilinear length results based on travel time of 66.67 m. The minimum transition curve length based on changes in the required data flexibility obtained a result of 67 m. The minimum transition arc length based on overcoming centrifugal force was obtained at 38.52 m. While the relative agility obtained a result of 54 m.

Superelevation calculations on this alternative road planning use the AASHTO method. The ideal actual speed is 80-90% of the plan speed, therefore the planned actual speed is 80% of the plan speed, so that a superelevation of 7.98% < 8% OK is obtained.

Based on the calculation of superelevation (e) at point P1 obtained a value of 7.98 ≥ 3%, then the type of horizontal curve used is *Spiral-Circle-Spiral* (S-C-S). The result of the calculation of superelevation obtained by the horizontal curve at point P1 is S-C-S. After knowing the type of curve, the next step is to calculate the parameters of the curve which is then carried out to determine the stationing point.

horizontal arch parameters. This side freedom area needs to be counted at every bend so that we can make sure the side area of the road will not obstruct the driver's view. The side freedom area on the corner is the space to guarantee freedom of view on the corner so that the stopping visibility (JPH) can be met. The planning basis for this calculation is the radius of the curve and the total length of the curve obtained from the calculation of the horizontal instrument. The value obtained is Ss < Lt then the side freedom required at the PI 1 bend point is 9.77 meters from the radius of the inner lane axis. The widening of the band is determined with the aim of maintaining operational service conditions at the corner. From the planning results obtained 0.37 [3]. For the results of the depiction after the calculation of the instrument, the next step is to make a superelevation diagram that has the purpose of guiding and clarifying the work in the field.

D. *Vertical Alignment Planning*

Vertical alignment is the planning of the elevation of the road axis at each point under review, in the form of an elongated profile. In the vertical alignment plan, there are positive slopes (climbs) and negative slopes (derivatives), so that the combination is in the form of convex curves and concave curves. Besides the two curves, there is also slope = 0 (flat). The calculation of the vertical curve in this final task, in determining the length of the vertical curve only uses stop visibility (JPH).

In planning Vehicle Stop Visibility (JPH) This determines the visibility of the vehicle so that the road feels safe and comfortable to drive. For the planned road with a design speed of 120 km / h obtained a stop visibility (Jph) of 250 m [3]. Based on results Flatness and arch type of alignment obtained value A = -1.6% > 0%, then the curve that occurs is a concave curve. The curved type is a concave curve, so the value is obtained vertical curved length, the one used is 121.88 m. While the results flatness and convex curved type in PVI 2 obtained a value of A = 2.57% > 0%, then the curve that occurs is a Convex Curve. Based on the results of the calculation of the criteria taken the largest value, the length of the curve used is 243.97 m.

E. *Pavement Planning Pavement Bending*

1) Basic Planning

The basis of road pavement for alternative designs of Pasuruan – Probolinggo Section IV Toll Road, the data that has been determined are as follows:

Road Classification	= Primary Artery
Road Type	= 4 lanes, bidirectional (4/2 D)
Year Opened	= 2023
Age Plan	= 20 Years
Core Pavement	= Bending
Basic Soil CBR	= 6%

2) CBR Data Management

The base soil CBR to be used in the design is 6% [4].

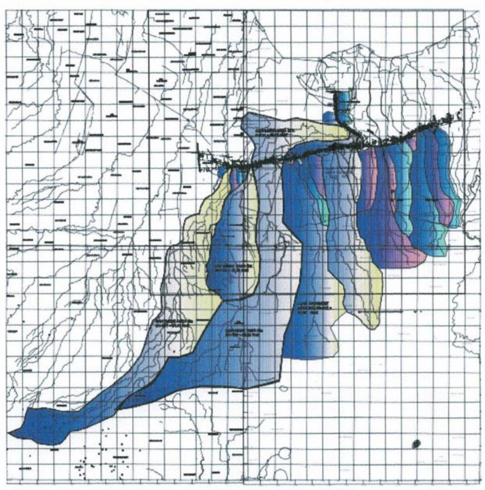

Figure 4 *Water Flow and Catchment Area*

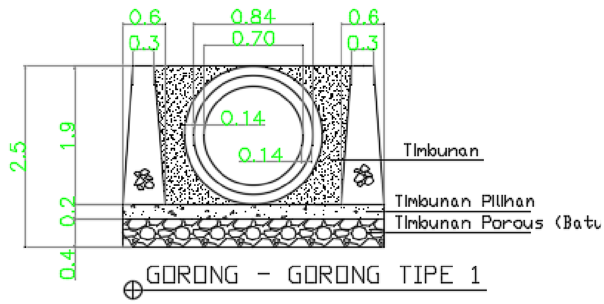

Figure 5 *Type 1 culvert*

3) Traffic Data Management

a. Average Daily Traffic

Average daily traffic data (LHR) is obtained from PT. Virama Karya Konsultan, with data obtained in the form of LHR from Pasuruan-Probolinggo road can be seen in Table 5. With this data taken in 2020 which shows that vehicles passing through the Pasuruan-Probolinggo flow in 2020 amounted to 6131 vehicles which will later be processed to become data during the year the toll road was opened, namely in 2023.

b. Annual Traffic Growth Rate

The traffic growth value is used as the growth of traffic rate to calculate the growth of traffic that will pass through the road design alternative plan according to the life of the road plan which is 20 years. The value of the traffic growth rate of 4.80% which is then calculated the growth of vehicle volume from 2020 to the planned year to open in 2023. The calculation of vehicle growth results obtained the number of LHR in 2023 for the type of 5-Axle Truck 72 junior high school / day. For other types of vehicles can be seen in Table 6.

4) Pavement Thick Design

In the design of road pavement using the Manual Pavement Method Number 04 / SE / DB / 2017 there are stages that need attention. The life of the plan obtained is 20 years. The traffic growth factor obtained is 4.8%. The number of vehicles will increase each year over the life of the plan. To calculate the traffic growth, a cumulative growth factor is needed where the result is 20.1.

Based on the Road Pavement Manual Number 04/SE/Db/2017, the calculation of vehicle axis load is calculated by the value *Vehicle Damage Factor* (VDF) calculated based on axle load weighing survey data. The VDF value can be seen in Table 7.

DD value is obtained at 0.5 and DL is 80%. To calculate ESA5 required commercial vehicle traffic volume in units of vehicle / day, the following is the volume can be seen in Table 8. The planning of the thickness of the bending pavement is planned based on the CESA5 value obtained from the calculation, so that the pavement thickness planning for 6% CBR for AC-WC 40mm, AC-BC 60mm, AC-Base 100mm, CTB 150mm, LFA Class A 150mm as shown in Figure 2.

F. Drainage Channel Planning

In planning alternative roads must meet drainage system standards. In this case, you must plan drainage when it rains, so that the water flowing on the surface can flow into the side channel to go to the drain so that puddles do not occur. In this drainage planning only calculates the dimensions of the edge channel used.

1) Rainfall Data

Rainfall data is used to plan the drainage of peripheral channels, the data used is the maximum daily rain data every year from 2006 to 2015 Probolinggo City.

2) Rainfall Data Management

In planning the drainage of roads required re-period rain intensity. This planning is determined by the re-period (T) of the planning year using the plan's life of 20 years.

3) Hydrological Analysis

To determine the flow discharge flowing on the plan road according to the age of the plan, a hydrological analysis is carried out. The parameters that can be used in this hydrological analysis are as follows.

1. Wet circumference of channel (P)
2. Wet cross-sectional area (A)
3. Transverse channel slope (i)
4. Calculation of hydrological discharge (Qhidrology)

4) Hydraulics Analysis

In the following hydraulics analysis, it aims to determine the cross-sectional ability to accommodate plan discharge in accordance with the age of the road plan. The parameters in calculating the flow discharge on the channel, namely:

1. Wet circumference of channel (P)
2. Wet cross-sectional area (A)
3. Transverse channel slope (i)
4. Calculation of hydraulic discharge (Qhirdrolika)

5) Culvert Dimension Design

The planning of culverts or transverse channels of the road is designed based on the watershed and catchment area around the planned road, so that the design process can be right on target and the main function of drainage to drain water can be achieved properly, in Figure 3 are the water flow areas around the planned road.

The culvert slope results of 0.73001322% which is still within the allowable 0.5% - 2% slope range.

CONCLUSION AND SUGESTIONS

A. Conclusion

Based on the results of research conducted on this geometric design plan, it can be concluded that the length of the plan road trace is 8575 m with an average slope of

0.87%, horizontal curves totaling 6 pieces with Spiral-Circle-Spiral and Full Circle types, 22 vertical arches, 11 having convex vertical arch types and 11 concave vertical arches. The existing road section has a road length of 8650 m with an average slope of 1%, horizontal curves totaling 6 pieces and vertical curves as many as 13 pieces.

The volume of excavations and piles in the geometric planning of Pasuruan-Probolinggo Toll Road Section IV-A is 9146 m3 for excavation and 1571084.9 for piles. Road pavement is designed using *Flexible Pavement* which is designed referring to the Road Pavement Design Manual (MDPJ) Year 2017 covering pavement on the road body and road shoulder: AC-WC thickness = 40 mm; Thickness AC-BC = 60 mm; AC-Base thickness = 100 mm; CTB thickness = 150 mm; LFA Class A thickness = 150 mm.

Drainage channels are designed using trapezoid-shaped channels, obtained 3 types of side channels. Type 1 : b = 1000 mm; h = 500 mm; w = 500 mm; m = 1. Type 2 : b = 1600 mm; h = 800 mm; w = 630 mm; m = 1. Type 3 : b = 2000 mm; h= 1500 mm; w = 870 mm; m = 1. For culverts designed 2 types. Type 1 : D = 0.7 m; h = 0.56 m and Type 2 : D = 1.1 m; h = 0.88 m. The difference in the volume of piles and the use of pavement which for the design of the plan uses flexible pavement while existing uses rigid pavement.

B. Suggestion

The use of adequate *devices* for the work and operation of AutoCAD Civil 3D software, as much as possible knowing the limits that can be done and knowing how to operate AutoCAD Civil 3D in detail. In addition, the use of more complete data will be very helpful in working on this plan, especially on rainfall data, LHR, and unit cost prices as detailed and complete as possible, this aims to produce optimal calculations and results.

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