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Geometric Design of Access Road Towards the Bailey Mountain Bentang Bridge

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ABSTRACT
Based on current conditions, Access to the Bailey Mountain Bentang Bridge has problems related to the road network, including steep slopes and sharp bends. Therefore, the geometric design of the access road to the Bailey Mountain Bentang Bridge Bridge is considered necessary as a solution to the problems that occur. The method used in this research refers to the RSNI T-14-2004 Standard on Urban Road Geometry and the Attachment to the Minister of Public Works Regulation No.19 of 2011 for the geometric design of roads and the design of this drainage section in the new Pd-T-02- 2006 –B concerning Road Drainage System Planning. Road design begins with conducting photogrammetry surveys, designing geometric roads, drainage, calculating the volume of cut and fill, using the appropriate provisions and standards in Indonesia. The results of surveys and geometric design of roads are then processed using the AutoCAD Civil 3D Program. This research resulted in a new road route with a road type of 2/2 UD, a lane width of 2.75 m, a design speed of 30 km/h, total road length of 569.06 m consisting of 5 points of intersection and 4 points vertical of an intersection. The drainage used is a U-Ditch precast with dimensions of 500 mm x 500 mm on both sides of the road.

Keywords: *Geometric Design, Access Road, Civil 3D, Drainage*

1. INTRODUCTION

Cikande road is a road that connects Bojonghaleuang Village with Jayamekar Village in West Bandung Regency. On Cikande road, there is Bailey Mountain Bentang Bridge which connects two areas of the village. The types of vehicles that often cross this bridge are motorcycles, cars, and light trucks. On this road users are forced to pull over when entering the bridge because the width of the road body is only able to load one truck. The width of the road is insufficient, as a result, road users must pull over if there are other road users from the opposite direction. Vertical alignment and horizontal alignment conditions are also not following the regulations. On this road, there was also a flood in 2004 from the overflow of the river so that the road could not be passed by residents The construction of this road is one of the alternatives to reduce traffic congestion, as well as avoid the danger of accidents that often occur at the site. Therefore, there needs to be a redesign of geometric access road to Bailey Mountain Bentang Bridge so that road users are comfortable when crossing the road

1.1. Calculation

Based on the design we did, we divided the calculation into two parts there are geometric road calculation and road drainage calculation.

1.1.1. Calculation of Road Geometric

Geometric calculation of roads refers to RSNI T-14 2004 Geometric Urban Road and Regulation of the Minister of Public Works No. 19 of 2011 Geometric Standards of Urban Roads. Before performing the calculation horizontal and vertical Alignment first performs the stopping sight distance calculation used as input data to perform the next calculation. Stopping sight distance serves as the minimum distance the driver needs to safely stop his vehicle[1] and is calculated using the formula $Ss = 0{,}278\ Vr\ x\ T + 0{,}039\ \frac{Vr^2}{a}$.

1.1.1.1 Calculation of Horizontal Alignment

Specifies the minimum bend radius value by using the plan speed value and maximum superelevation with the formula $Rmin = \frac{Vr^2}{127(emax+fmax)}$ Vr is the emax plan speed is the maximum superelevation and fmax is the swipe coefficient for asphalt hardening [1]. The curve transition is used as a transition from the straight section of the road to the curve of the road. The minimum curve transition is calculated using the largest values of $Ls = \frac{Vr}{3,6}T$ and Ls = W. $\Delta^{-1} - 1$. (ed + eNC) where T is the travel time on the curve transition (2 seconds), Δ is the maximum transverse slope change rate, W is the width of one lane of traffic, eNC is the normal cross slope of the road and ed is the superelevation value of the plan. Horizontal alignment has three types of bends namely full circle, spiral circle spiral and spiral spiral. Full circle is a bend that is in the shape of a full circle arc. Not all curves can be made full circle, only curves with large radius are allowed. Full circle can only be selected for a large radius with the required superelevation ≤ 3% [1]. Full circle is calculated using the equations Tc = Rc tan ½ Δ, Ec = Tc tan ¼ Δ and $Lc = \frac{\Delta.2\pi.Rc}{360^0}$ where Tc is the straight length from the beginning of the bend to the PI, Rc is the radius of the plan, Δ is the corner of the bend, Ec distance PI to the arc of the circle and Lc is the length of the circle arc. Spiral Circle Spiral is a bend consisting of 1 circle arch and 2 spiral curves. The transitional curve is placed between the straight part and the circle section, which is before and after the bend in the shape of the circular arc [1]. Spiral Circle Spiral is calculated using the equation Lt = Lc + 2Ls. Where Lc is the part of the circle and Ls is the length of the transition curve and Ls is the length of the curve transition. The spiral circle spiral bend requirement is the values Δc > 0°, p > 0.2, e > 4% [1]. Spirals are curves without circular arcs or bends consisting of two spiral arches. Spiral spirals are calculated using the equation Lt= 2Ls, where Lt is the total length of the curve and Ls is the length of the spiral curve. The spiral bend does not have a curved part of the circle, then the value of Lc = 0

1.1.1.2 Calculation of Vertical Alignment

Vertical alignment consists of a straight section and a curved part that is reviewed from the starting point of planning. Vertical curves can be sag or crest, straight parts can be positive ramps of the climb or derivative negative ramps or flat zero ramps [1]. At RSNI T-14-2004 Geometric Urban Road [1], vertical curved are set in the form of simple parabolic. Sag vertical curved length can be determined using stopping sight distance and vertical curved values (K). If the sight distance is smaller than the length of the vertical curved then the equation is used $L = \frac{A.S^2}{658}$ with L is the length of the curved, A is the algebraic difference in grades and S is stopping sight distance (35m). The value A is determined by the equation G2 – G1 with G2 is the elongated slope of the path after PVI, and G1 is the elongated slope of the path before PVI. If the visibility is greater than the length of the vertical curved then the equation L= 2S - $\frac{658}{A}$ Using the vertical curved value (2) then the length of the vertical curved is calculated with the equation, $L = \frac{K}{A}$. The length of the sag vertical curved can be determined using the stopping sight distance and vertical curved value (K). If the sight distance is smaller than the length of the vertical curved then the equation $L = \frac{A.S^2}{120+3.5S}$ with L is the length of the vertical curve. If the sight distance is greater than the length of the vertical curved then the equation L= 2S - $\frac{120+3.5S}{A}$. By using the vertical curved value (6) then the length of the vertical curved is calculated with the equation, $L = \frac{K}{A}$. The calculation is followed by determining the vertical shift value of the center point of the circle arc (Ev) using the Equation, $Ev = \frac{A.L}{800}$.

1.1.2. Calculation of Road Drainage Dimensions

In performing the design of a cross-section of road drainage carried out hydrology analysis and hydraulic analysis. Hydrology analysis is carried out to obtain flood discharge using maximum daily rainfall data while hydraulic analysis is carried out to design a drainage cross-section so that it can accommodate the discharge volume of the plan. This cross-section of drainage design refers to the Pd-T-02-2006-B guidelines on Road Drainage System Planning. Rainfall data is useful for analyzing runoff discharges from rain catchment areas. At our planning site, there are two nearby stations namely Cimeta rain station and Cicangkan rain station, but due to the Covid-19 pandemic, data retrieval cannot be done to the location. So another alternative is to use secondary rainfall data that has been found in other nearby locations, namely Husein Sastranegara airport rain station.

1.1.2.1 Hydrology Analysis

Determine the rainfall frequency analysis to find out the type of distribution. The analysis of rainfall frequency is calculating using the distribution of Log Pearson III with a five-year re-period [3]. The intensity of rainfall used refers to van Breen's Jakarta Intensity Duration Frequency (IDF) curve by looking for the smallest square in some equations. This is used because there is no short rainfall data available but only daily rainfall data from Husein Sastranegara station.

Referring to the results of research by Ir. Van Breen in Indonesia on Java Island, daily rain concentrated for four hours with a total thickness of rain of 90%. Thus the intensity of rain for the observation site is, $I_{240} = \frac{90\% \times Xt}{4}$. Furthermore, calculate the difference from the intensity of the planned rain in the five years period at the observation site to the rainfall intensity of the Jakarta/IDF Van Breen base, with the intensity of the rainfall being 240 minutes and the five years period in van Breen rainfall intensity is 27 mm/h. So the difference becomes, $I_{difference} = I_{Jakarta} - I_{location}$. After obtaining the intensity of rainfall of various durations that occur at the observation location, then calculate the value of the tribes in the rain intensity equation, using the Talbot equation (1881). The calculation of the debit plan is carried out using the equation, $Qa = \frac{1}{3{,}6}\ x\ C\ x\ I\ x\ A$, with Qa being the flow discharge, C is the coefficient of draining [3], I is the intensity of rainfall, and A is the area of the flow area with a width limit of 10 m for the dense home area [3].

<u>*1.1.2.2 Hydraulic Analysis*</u>

Calculation of drainage dimensions using the trial & error method with condition Qa < Qs. Flow channel (Qs) obtained by using equation Qs = V x F, with V is the flow speed obtained using the equation $V = \frac{1}{n}\ x\ R^{2/3}\ x\ i_g^{1/2}$ with R is a cross-sectional hydraulic radius that can be determined by the equation, $R = \left(\frac{b\ x\ h}{b+2h}\right)$. F is a wide cross section of drainage. The cross section used is a rectangular cross section, then the value F can be determined using the equation $F = b\ x\ h$ with b being wide and h being the height of the dimensions.

1.2. Related Work

Safana and Fathurrachman [4] have the same variables as this study. Besides, all research has a similar method, namely geometric calculation of the path of Bina Marga method and using Autocad Civil 3D software in the process of design workmanship. Shidiq [5] has a similar location in Bailey Bridge Gunung Bentang Bojong Haleuang West Bandung Regency. However, our research is different from previous research, due to Shidiq [5] which did design the upper structure and structure under the bridge at the existing site. Raji et al [10] and Mandal et al [9] have the similarity with this research, which is on the use of Autocad Civil 3D in the design process. The biggest difference between our research and Raji et al [10] and Mandal et al [9] is that we calculate drainage dimensions on our research and also the road we design is a urban road, while the road they design is a highway [9] [10].

1.3. Our Contribution

This paper discusses road geometric design and drainage dimensions design based on previous research by exploring the application of Autocad Civil 3D software in the design process. If in shidiq [5] the construction of bridges uses existing locations, then we create a new route to provide safety and comfort for road users. In this paper, the geometric design uses RSNI T-14-2004 and Regulation of the Minister of Public Works No. 19 of 2011 on geometric urban roads. The design of dimensions drainage uses PD T-02-2006-B regulations on the planning of road drainage systems. We use topographic maps of Indonesia's Geospatial Agency with a scale of 1:25000 and intervals of 12.5 meters. This topographic map then processed using Autocad Civil 3D software so that the contour surface shapes into 3 dimensions and is interconnected with the results of geometric road design.

1.4. Paper Structure

The rest of the paper is organized as follows. Section 2 contains research methods including geometric design and drainage design results. Section 3 contains design conclusions and suggestions for future research.

2. BACKGROUND

The purpose of this research is to design geometric roads that are safe and convenient for road users and design dimensions of road drainage using Autocad Civil 3D software to facilitate the design process.

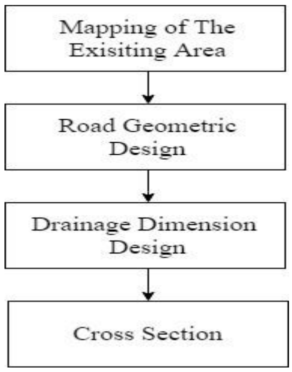

Figure 1 Methodology

2.1. Mapping of The Existing Area

The research site is located in a hilly area and is a residential area, therefore it is necessary to do the process of mapping the area visually with the help of drones so that during the process of determining the route of the road does not take land owned by residents. The existing area mapping process has the following steps:

1. Placement of Ground Control Point (GCP) through Google Earth. The route flies using Pix 4D for DJI, and sign-making for GCP;
2. GCP installation in the field, Aerial Photo Capture, and GPS coordinate retrieval. There are seven GCP used in GPS coordinate retrieval at Bojonghaleuang Village location. Coordinates were taken from SOKIA GCX 2 Geodetic GPS tool;
3. After existing data is obtained in the form of aerial photos as many as 889 photos and 7 GCP coordinates, then perform the process of creating

satellite imagery using Agisoft Metashape software;

4. Topographic maps of the Indonesian Geospatial Agency are then processed using Autocad Civil 3D software for tighter intervals and during the geometric road design process, contours and geometric design results are interconnected.

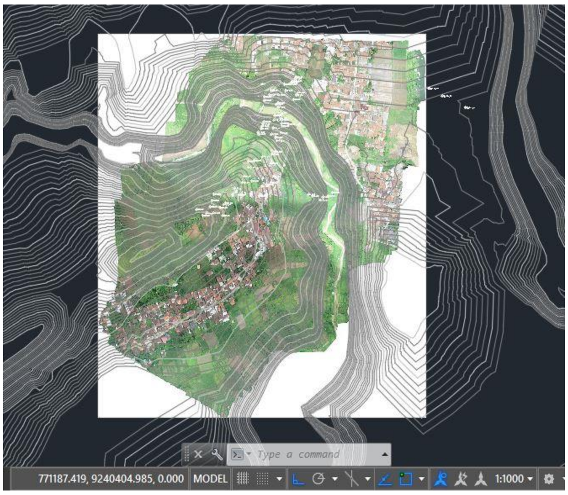

Figure 2 Mapping of the existing area

2.2. Road Geometric Design

2.2.1. Design of Horizontal Alignment

The horizontal alignment design starts by specifying the slice point. This PI determination is done as much as possible to avoid land owned by residents. At the determining stage of this PI is obtained 5 PI pieces which can be seen in figure 3.

Figure 3 Determination of the Point of Intersection

The result of determining this PI is obtained coordinates from PI, these coordinates are then used to get the value from the corner angle (Δ).

Table 1. Bend Angle Value

PI	STA	Koordinat		α	Δ
		X	Y		
A1		771,939,118	9,241,193,539	280,994	
1	0+079.96	771,860,582	9,241,208,796	288,484	7,490
2	0+204.8	771,742,223	9,241,248,362	195,873	92,611
3	0+335.68	771,699,626	9,241,098,559	118,572	77,302
4	0+434.48	771,801,689	9,241,042,978	222,121	103,549
5	0+523.06	771,734,103	9,240,968,233	213,157	8,964
A2		771,708,885	9,240,929,632		

Once the corner is obtained, then the type of bend can be determined and calculating. The result of determination and calculation of this type of bend gets a result bend type FC 2 pieces, SCS type 2 pieces, and type SS 1 pieces.

Table 2. Results of Horizontal Alignment Calculation

Component		*Point Of Intersection*				
Descp	Unit	1	2	3	4	5
STA		0+079.96	0+204.71	0+335.68	0+434.48	0+523.06
Bend Type		FC	SCS	SS	SCS	FC
Δ	°	7,490	92,611	77,302	103,549	8,964
R	m	500	35	30	27	360
Ls	m	-	35,661	40,455	36,575	-
Θs	°	-	29,203	38,651	38,827	-
Xc	m	-	34,735	38,615	34,897	-
Yc	m	-	6,056	9,092	8,258	-
P	m	-	1,607	2,521	2,292	-
k	m	-	17,658	19,878	17,969	-
Δc	°	-	34,204	-	25,895	-
Lc	m	65,333	20,883	-	12,197	56,294
Ts	m	32,730	55,972	45,887	55,158	28,219
Es	m	1,070	17,991	11,642	20,340	1,104
Lt	m	65,333	92,205	80,909	85,347	56,294
e	%	NC	7,8	8,0	8,0	2,5

Superelevation diagramming is processed by Autocad Civil 3D software, but due to the standard differences used between Autocad Civil 3D software and manual calculation results, improvements must be made to the superelevation diagram.

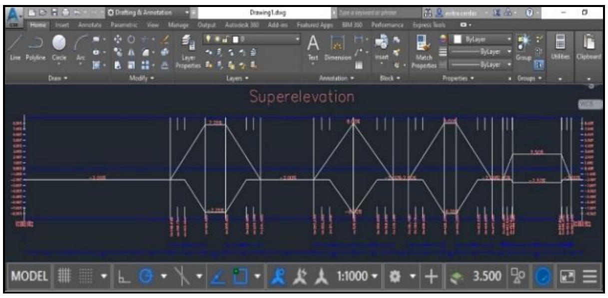

Figure 4 Diagram Superelevation

The result of road geometric design can be seen in figure 5.

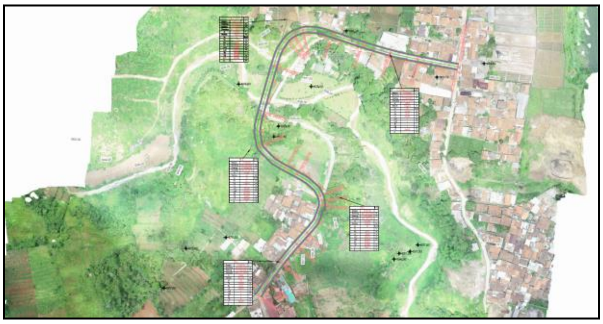

Figure 5 Result of Geometric Design

2.2.2. Design of Vertical Alignment

Vertical Alignment design starts by making the existing land long section with Autocad Civil 3D automatically. Furthermore, determining the PVI on the long section that has been made, the determination of PVI is carried out on the condition that the slope of the road should not exceed 10% [2]. The result is 4 pieces of PVI on the existing long section that can be seen in figure 6.

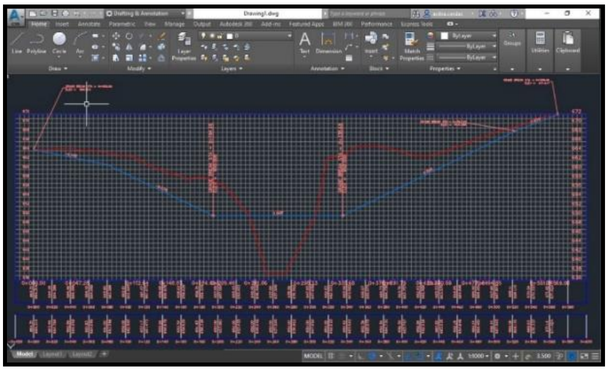

Figure 6 Determintion PVI in Long Section

From the PVI determination, the next step is the calculation of thr algebraic difference in grades (A), gradient (G), and determination of the type of curved.

Table 3. Results of algebraic difference in grades (A) and gradient (G) Calculation

PVI	G	A	Curved Type
Start			
	-0.0414457		
PV1		-0.0542148	CREST
	-0.0956605		
PVI2		0.0956605	SAG
	0		
PVI3		0.0979555	SAG
	0.0979555		
PVI4		-0.0226677	CREST
	0.0752877		
End		-0.0752877	

The vertical alignment consists of a vertical shift of the center point of the circular curved (Ev), the length of the vertical curved (L) and the sight distance (S).

Table 4. Results of Vertical Alignment Calculation

PVI	S	L	Ev
PVI 1	35	10.842954	0.073481
PVI 2	35	48.323341	0.5778293
PVI 3	35	49.482665	0.6058873
PVI 4	35	4.5335498	0.0128457

2.2.3. Coordination Beetwen Horizontal Alignment and Vertical Alignment

Alignment coordination is done so that geometric design results are safe and convenient for road users. The requirements of coordination of alignment are as follows:

1. Horizontal alignment narrowed with vertical alignment, with a longer horizontal alignment length slightly enclosing vertical alignment;
2. There are no two vertical curves in one horizontal bend;
3. No sharp bends;
4. No vertical alignment peak that blocks the view.

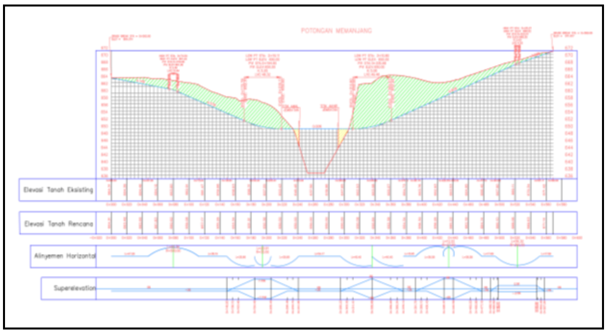

Figure 7 Coordination beetwen Horizontal Alignment and Vertical Alignment

2.3. Drainage Dimensions Design

2.3.1. Hydrology Analysis

Hydrology analysis calculations begin by performing the calculation of rainfall distribution, the method used is Log Pearson III distribution. Furthermore, the calculation of the five-year rainfall re-period [3]. Rainfall Intensity Calculation refers to Jakarta Intensity Duration Frequency (IDF) by Van Breen.

Table 5. Results of IDF Jakarta Curve Shift

5 year periode		
Idifferens	-1.112 mm/hour	
Duration	Rainfall Intensity	
(minutes)	IDF JKT (mm/hour)	Ilocation (mm/hour)
5	148	149.112
10	126	127.112
20	114	115.112
40	87	88.112
60	72	73.112
120	45	46.112
240	27	28.112

After obtaining the intensity of rainfall of various durations that occurred at the observation site, further calculating the value of the tribes in the rain intensity equation, the equation used was the Talbot equation (1881). The results of calculating rainfall intensity with the equations Talbot (I), Area Area (A), and Coefficient of flow (C) can be seen in tables 6 and 7.

Table 6. Results of Rainfall Intensity, Catchment Area and Drainage Coefficient on Left Drainage

STA from - to		C	I (mm/hour)	A
0+000	0+50	0.8	159.115	162.5
0+50	0+100	0.8	159.115	162.5
0+100	0+150	0.8	159.115	162.5
0+150	0+200	0.8	159.115	162.5
0+200	0+243	0.8	159.119	139.75
0+293	0+350	0.8	159.111	185.25
0+350	0+400	0.8	159.115	162.5
0+400	0+450	0.8	159.115	162.5
0+450	0+500	0.8	159.115	162.5
0+500	0+569.06	0.8	159.104	224.445

Table 7. Results of Rainfall Intensity, Catchment Area and Drainage Coefficient on Right Drainage

STA from - to		C	I (mm/hour)	A
0+000	0+50	0.9759	159.053	1350
0+50	0+100	0.9727	159.055	1190.95
0+100	0+150	0.2415	159.069	662.5
0+150	0+200	0.2415	159.073	662.5
0+200	0+243	0.2415	159.060	569.75
0+293	0+350	0.4075	159.062	755.25
0+350	0+400	0.4075	159.069	662.5
0+400	0+450	0.9863	159.049	2366.1
0+450	0+500	0.9893	159.042	3035.95
0+500	0+569.06	0.9824	159.040	2547.8306

2.3.1. Hydraulic Analysis

Calculation of drainage dimensions is used trail & error method at the width and height of drainage with the condition Qa<Qs. The width of drainage is tried 0.5 meters and the height is tried 0,2 meters.

Table 8. Results of Flow at Drainage

STA from - to		Qa (m3/second)		$Q_{s\ left\ and\ right}$ (m^3/second)	Information
		Left	Right		
0+000	0+50	0.0016	0.0162	0,294	Qualify
0+50	0+100	0.0016	0.0142	0,363	Qualify
0+100	0+150	0.0016	0.0020	0,446	Qualify
0+150	0+200	0.0016	0.0020	0,342	Qualify
0+200	0+243	0.0014	0.0017	0,270	Qualify
0+293	0+350	0.0018	0.0038	0,234	Qualify
0+350	0+400	0.0016	0.0033	0,447	Qualify
0+400	0+450	0.0016	0.0286	0,452	Qualify
0+450	0+500	0.0016	0.0369	0,451	Qualify
0+500	0+569.06	0.0022	0.0307	0,416	Qualify

The design of the guard height (W) is calculated using the equation $W = \sqrt{0.5h} = \sqrt{0.5\ x\ 0.2} = 0.3\ meters$. Therefore, the design of drainage dimensions uses a concrete rectangular shape with dimensions of 500 mm x 500 mm.

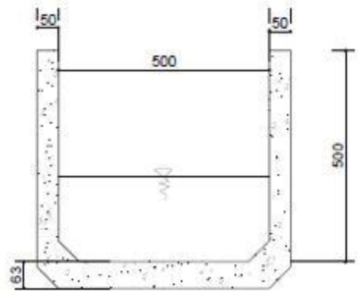

Figure 8 Drainage Dimensions

2.4. Cross Section Design

Cross-section creation is the beginning of the calculation of cut and fill volume. Cross-section creation is done automatically using the Autocad Civil 3D software. The results cut volume is 27718.80 m³ and the fills volume is 608.43 m³.

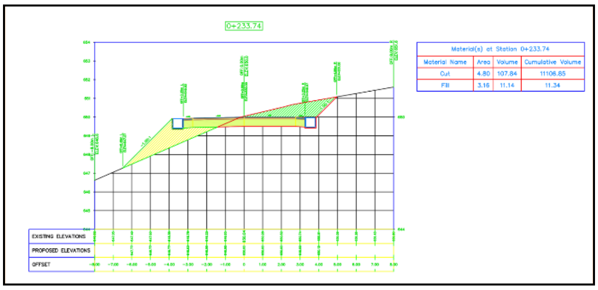

Figure 9 Example Cross Section, Cut & Fill Volume at STA 0+233.74

3. CONCLUSION

This paper obtained the results of the design of a 569.09 m road with a speed design of 30 Km / hour. In vertical alignment there are 4 PVI with a cut volume is 27718.80 m3 and a fill volume is 608.43 m3. Then in the horizontal alignment, type of bend planned two full-circle type bends, two spiral-circle-spiral type bends, and one spiral-spiral type bend. Traffic lane width is 5.5 meters with left and right shoulder of 0.5 meters and drainage dimensions of 500x500 millimeters. For more maximum results it is necessary to simulate the vehicle on the planned route, as well as the contours used should use the contours of the photogrammetry survey results to keep the volume of cut and fill close to the actual results in the field.

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