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Implementation of Autocad® Civil 3D for Cut and Fill Calculation of Margoyoso Road Section BTS, Jepara – Kudus Regency

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ABSTRACT

The small and medium-sized industry in Jepara Regency has shown significant progress, with one of the most notable small industries in Margoyoso Village being the monel craft industry. Good infrastructure support, such as Margoyoso Road, undoubtedly contributes to the local economy. One indicator of good infrastructure development is efficiency in terms of time and cost. This paper discusses the implementation of AutoCAD® Civil 3D in cut-and-fill calculations. The calculation process using AutoCAD® Civil 3D with the cross-section method resulted in a cut volume of 57,581.60 m^3, a fill volume of 31,952.90 m^3, and a net volume of 25,628.70 m^3. These results prove that the implementation of AutoCAD® Civil 3D provides faster, more accurate, and more precise data.

1. Introduction

The development of road infrastructure in Indonesia has increased rapidly in recent years. This program supports government programs to improve each region's economy. Urban infrastructure is a multifaceted concept beyond engineered facilities, utilities, and systems. It is equally a place for local and global governance, intertwining economic growth, climate change, and municipal waste. The concept of sustainability is relatively new encompassing a multidisciplinary field of engineering, economic, social, and environmental sciences. Research in sustainable urban infrastructure is a new and ever-evolving field [1, 1]. Jepara is the northernmost region in Central Java, where the population continues to increase every year. According to the data from the Central Statistics Agency of Jepara, 2022; the population was 1,192,811. Jepara serves as a center for government and economy, which leads to traffic congestion and overcrowding on certain roads. Road infrastructure plays a vital role in driving economic growth. Insufficient infrastructure is one of the critical obstacles to faster economic growth in a country [2]. Adequate road infrastructure supports smooth business processes and accelerates the distribution of products from one place to another. Additionally, the availability of road infrastructure also supports growth in various areas such as educational zones, office areas, and commercial areas.

Geometric road design encompasses horizontal alignment and vertical alignment to provide comfort and safety for road users. Geometric road design includes planning the road alignment, shoulders, curves, drainage, and cut and fill. The method of road geometry is a crucial aspect of road design that focuses on creating the physical layout of the road to facilitate efficient, smooth, safe, comfortable, and effective traffic operations [3].

Construction activities in road infrastructure development are always accompanied by earthworks, which can sometimes be a challenge like differences in contour at the construction site necessitate excavation and embankment activities (cut and fill) [4]. When planning the vertical alignment in road geometry, we must consider the volume of excavation and embankment calculations properly. To analysis the calculation of cut and fill volumes, engineers use Autocad® Civil 3D.

The ability of AutoCAD® Civil 3D eliminates the main drawbacks of manual design approaches, which are impractical, time-consuming, and highly susceptible to errors that may occur [5]. This research will attempt to assess cut and fill volume calculation using AutoCAD® Civil 3D, with a case study on the Margoyoso BTS Road Section in Jepara - Kudus District. The benefits obtained from this research include speeding up the volume calculation process and improving the accuracy of the calculation results.

2. Literature Review

2.1 AutoCAD® Civil 3D

AutoCAD is a software developed by Autodesk which is used to create 2D and 3D drawings. AutoCAD is commonly used by civil engineers, architects, interior designers, and mechanical engineers. It is a versatile computer program with limitless applications and can be used at various scales. Autocad is the most commonly used program by engineers and technical professionals [6]. Technology continues to advance, particularly in the field of construction. Currently, AutoCAD software enables engineers efficiently plan building structures. Even novice engineers can learn AutoCAD through self-study. AutoCAD® Civil 3D can maximize the geometric design of roads with various practical concepts [7]

AutoCAD® Civil 3D is an application developed by Autodesk. It is software used to facilitate planning oconstruction projects, such as buildings, roads, or bridges. Civil 3D is well-established in civil engineering and is commonly used in various large and small construction projects [8]. In addition, AutoCAD® Civil 3D produces more accurate designs and calculations, thereby minimizing errors during the building design process.

Road geometry design using AutoCAD® Civil 3D software can save costs and accelerate the planning process compared to manual methods. With the use of AutoCAD® Civil 3D software, the design process of a flyover road becomes more efficient, accurate, and time-saving compared to designing the same road using manual methods [9]. One example of the convenience in geometric planning using AutoCAD® Civil 3D software is its ability to integrate with mapping applications, allowing the generation of elevation data on contours.

2.2 Geometric Road Design

Road construction is creating transportation corridors to overcome various geographical challenges. It involves budgeting, planning, implementation, and maintenance. Developing and transport infrastructure can improve community satisfaction [10]. However, road construction also brings negative impacts. Therefore, proper geometric road design is necessary to ensure effectiveness. With attention to this, the geometric design of roads is the optimal geometric design of roads [11]

Geometric road design is a part of road planning that focuses on the road's physical form and essential functions, which is to provide optimal service for traffic flow and travel access. When planning the geometric design of a road section, it is necessary to refer to applicable regulations that are adjusted based on available supporting data and field survey results. A safe road is planned and designed to meet standards, and this is highly trusted by many road designers [12].

Parameters for geometric road design include ensuring traffic comfort and safety, such as design vehicle, design speed, road volume, and road capacity. A base map is needed to depict the alignment to realize these parameters, horizontal and vertical alignment of the road. Planning horizontal and vertical alignment is inseparable from contour data, as contours are necessary to avoid errors in the planning process and ensure accurate road alignment [13]. Geometric road design is obtained through an analysis that meets design criteria. Design criteria in geometric planning include cross-sectional elements, visibility, vehicle stability, driver comfort, traffic characteristics, and economic factors [14]. Inaccurate geometric road planning can lead to traffic accidents. Accidents commonly occur due to several factors, including drivers' lack of alertness when dealing with obstacles while driving, road geometry that does not meet standards, and vehicle factors, such as being unfit for use or lacking maintenance [15]

Roads are essential infrastructure and vital transport routes [16]. Roads serve a significant role as indicators of development distribution and as links between regions. Another function of roads is to stimulate economic activity in a region, as they allow people to travel easily and expedite the transportation of commodities. Roads can also be classified as highways or toll roads. According to their status, public roads are grouped into; national roads, provincial roads, district roads, city roads, and village roads [17]

Highways, or also known as main roads, connect one region to another. Highways are critical role as transportation routes in various urban and rural community activities. Furthermore, highways have a significant impact as infrastructure for moving people and goods. In China, green highways have been constructed in recent years to mitigate the negative environmental impacts of highway construction [18].

Highways are not only means of transportation but also contribute to economic growth, especially in remote areas, by facilitating access from those regions to city centers. Urban-industrial land and highway networks are primary components of urban land and transportation systems, respectively, and substantially impacts on social and economic development [19].

3. Method

3.1 Research sites

This research's road design case study is the Margoyoso Road, located in Kalinyamatan District, Jepara Regency, Central Java. This road connects Jepara Regency with Kudus Regency. The location of this road is highly strategic as it serves as a main road and supports the economic growth of the people in Jepara Regency. Furthermore, Margoyoso Road is connected to the Kudus Ring Road, which leads directly to Kudus Regency. The Margoyoso Road section consists of two segments with a total length of 2,395 meters.

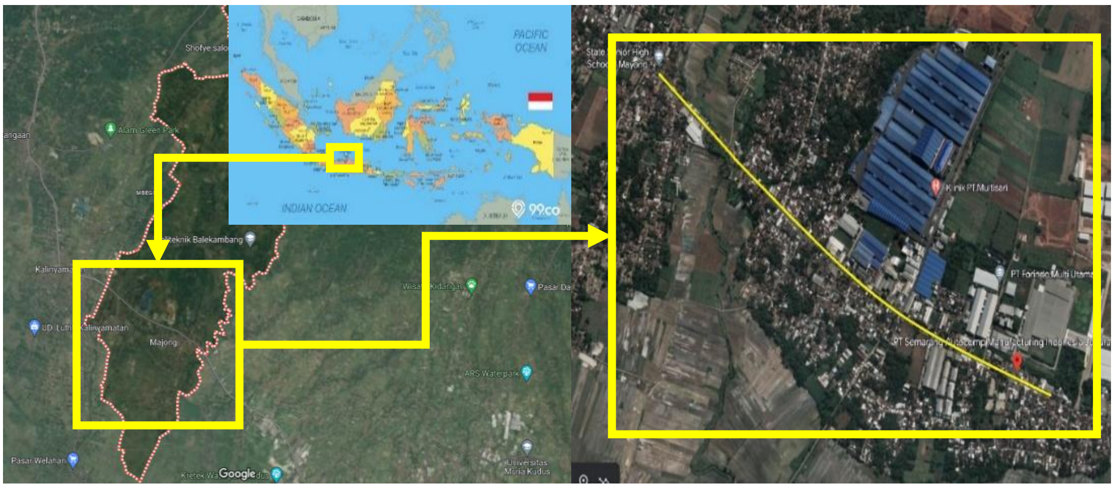

Figure 1 Research Location Map
Source : Google Earth

In this paper, the author performs cut and fill calculations using the implementation of AutoCAD® Civil 3D software and the cross-section method. The data used in the case study for cut and fill calculations are secondary data obtained from relevant institutions including map of the roads in Central Java Province, map of the study case location (Margoyoso Road BTS, Jepara – Kudus, initial coordinate points and final coordinate points. The data obtained is according to the plan in the research so that it is precise and appropriate [20]

The methods involved in this process include preparation, data collection, and cut and fill calculations using AutoCAD® Civil 3D. The following are the step-by-step procedures for cut and fill calculations, setting coordinate system in Civil 3D, Inputting point data, and Creating contours.

4. Result and Discussion

In the process of cut and fill calculations, it is necessary to classify the road as part of determining the design criteria. Based on the "Pedoman Desain Geometrik Jalan" (Guidelines for Geometric Road Design), Margoyoso Road between Jepara and Kudus can be classified as Class I Arterial Road with two lanes and four lanes. Once the road classification is determined, the design criteria for the road can be established, which can be seen in Table 1.

Table 1 Kriteria design Jalan Margoyoso Bts Kab. Jepara – Kudus

No.	Design Criteria	Value
1	Road Network System	Secondary
2	Road Function	Artery
3	Road Status	City Government Road
4	Road Class	I
5	Road Terrain Classification	Flat (< 10%)
6	Lane Configuration	4/2 T
7	Velocity Design, V_D	80 km/hour
8	Normal Super-elevation, e_n	2%
9	Maximum Super-elevation, e_{max}	8%

The data processing process using AutoCAD® Civil 3D 2024 Metric requires importing coordinate data obtained from geographic mapping software, such as Global Mapper®. We can import point data in *.csv format using the "Points - Points Creation Tools" menu to obtain contours. The next step is to create a surface by right-clicking on the "Surface" panel in the Toolspace and selecting "Create Surface - Rename 'Existing' - OK." To merge the imported points into contours, right-click "Point Group - Add all points - OK." The resulting contours can be seen in Figure 2.

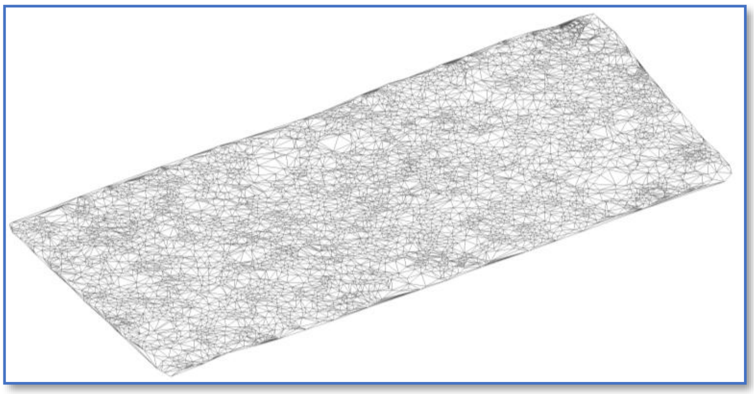

Figure 2 3D contours in AutoCAD® Civil 3D 2024 Metric

Two Spiral Circle Spiral (SCS) curves were obtained from the alignment design on Margoyoso Road between Jepara and Kudus. The results of the horizontal alignment calculation using AutoCAD® Civil 3D can be seen in Table 2.

Table 2 Bend Calculation Results

SCS	Civil 3D Design		
	PI 1	PI 2	Sat
Vr	80	80	km/jam
e_{max}	8	8	%
f_{max}	0,14	0,14	
R_{min}	229,0623	229,062	m
Δ (o)	7,763	9,695	o
Ls	70	60	m
P	0,2722	0,2727	
θs	2,6738	3,1252	
Rc	750	550	m
Lc	31,62	33,07	m

The existing profile was obtained in the horizontal alignment planning to determine the elevation changes along the alignment.

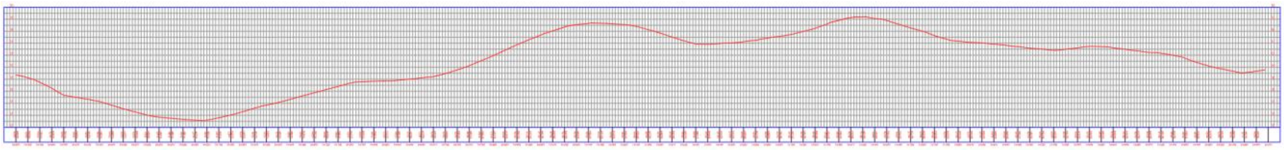

Figure 3 Existing Profile of the Planned Trace

After conducting the vertical alignment planning, five PVI (Point of Vertical Intersection) were obtained, consisting of 2 concave curves and Three convex curves. The design alignment can be seen in Figure 5.

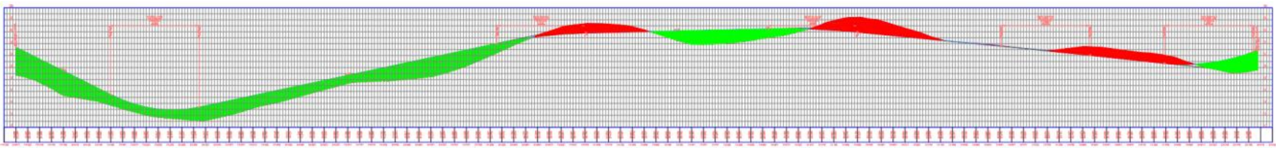

Figure 4 Design Alignment Vertical

Based on the results of the horizontal alignment, projections can be made to generate the vertical alignment calculations, which can be seen in Table 2.

Table 3 Vertical Alignment Calculations

VPI	Jenis Lengkung	Grade (%)	Lv (m)	K Value
1	Cekung	-4.94%	150.00	21.23
2	Cembung	2.12%	150.00	79.13
3	Cembung	0.23%	150.00	125.89
4	Cekung	-0.97%	150.00	1,358.27
5	Cembung	3.61%	150.00	32.02

In the corridor creation process, the Assembly Process is carried out beforehand to determine the cross-sectional design of the road and the planned slope. Based on the cross-sectional planning, several road elements can be identified, including the median, traffic lanes, and roadside channels.

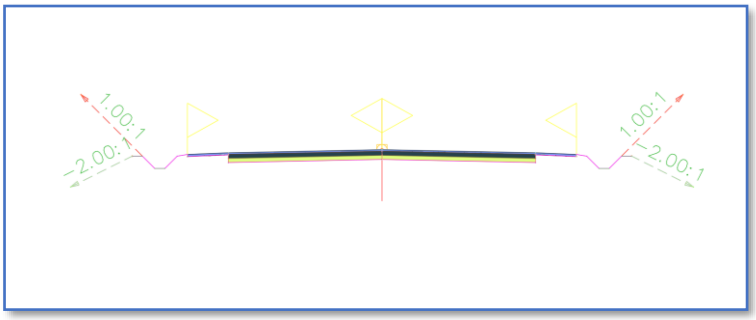

Figure 5 Assembly Centerline

The corridor process is the final stage of road planning using AutoCAD® Civil 3D. The "object view" function can be used, which allows the display of a 3D road model to view the results of the corridor process. Figure 6 represents a section of the successfully completed corridor process.

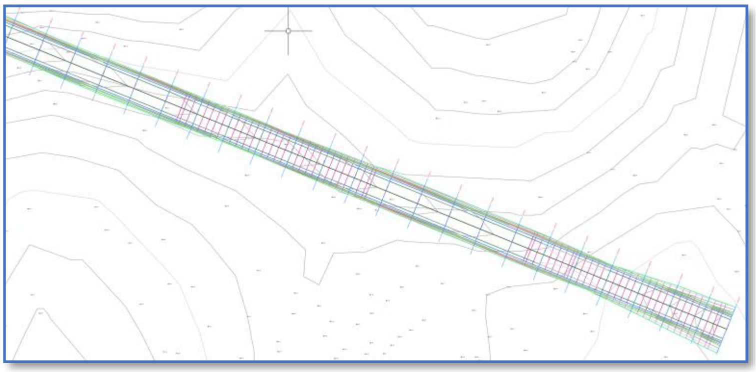

Figure 6 Corridor

Once the assembly and corridor are completed, the cut and fill volumes can be obtained by creating section views at each Station (STA). Here are the results of the section views: green represent fill sections, while red represents cut sections.

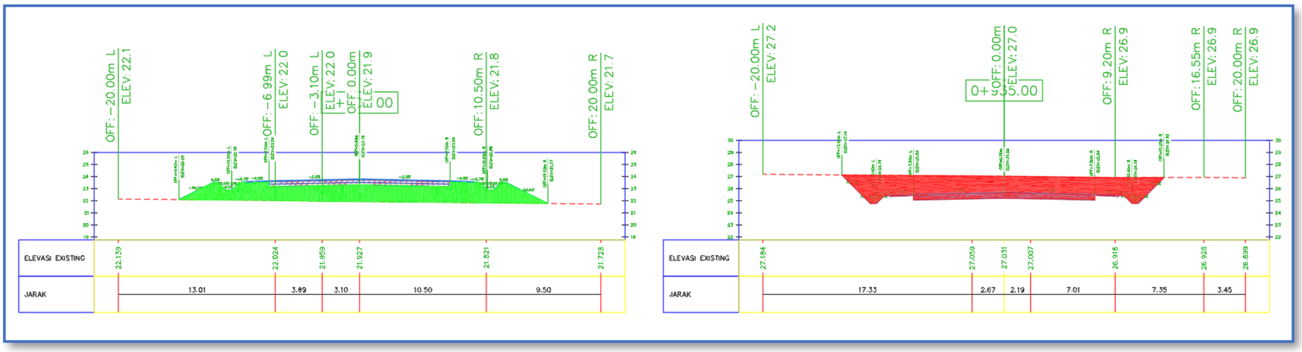

Figure 7 Section View Cut and Fill

After determining the design criteria and performing cut and fill calculations using AutoCAD® Civil 3D 2024 Metric with the cross-section method, the results are as follows: the volume of cut is 57,581.60 m^3, the volume of fill is 31,952.90 m^3, and the net volume is 25,628.70 m^3. The calculation results using AutoCAD® Civil 3D 2024 Metric can be seen in Figure 8.

Total Volume Table						
Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
1+775.00	0.00	30.17	0.00	592.10	53260.47	22620.57
1+800.00	0.00	44.45	0.00	932.71	53260.47	23553.28
1+825.00	0.00	50.36	0.00	1185.16	53260.47	24738.43
1+850.00	0.00	50.03	0.00	1254.97	53260.47	25993.40
1+875.00	0.00	48.46	0.00	1231.23	53260.47	27224.63
1+900.00	0.00	47.62	0.00	1201.12	53260.47	28425.75
1+925.00	0.00	48.25	0.00	1198.37	53260.47	29624.13
1+950.00	0.00	42.97	0.00	1140.24	53260.47	30764.37
1+975.00	0.00	23.08	0.00	825.66	53260.47	31590.03
2+000.00	0.92	2.98	11.49	325.68	53271.96	31915.71
2+025.00	20.96	0.00	273.43	37.19	53545.39	31952.90
2+050.00	51.25	0.00	902.58	0.00	54447.97	31952.90
2+075.00	71.59	0.00	1535.54	0.00	55983.51	31952.90
2+095.32	85.70	0.00	1598.09	0.00	57581.60	31952.90

Figure 8 Calculation results AutoCAD® Civil 3D 2024 Metric

5. Conclusion

In conclusion, the paper on calculating cut and fill volumes using AutoCAD® Civil 3D yielded a volume of cut of 57,581.60 m^3 and a volume of fill of 31,952.90 m^3. The deliberate speed (Vr) used was 80 km/h, resulting in a maximum superelevation slope (e_{max}) of 8% and a transverse friction coefficient (f_{max}) of 0.14. These results demonstrate that the implementation of AutoCAD® Civil 3D provides faster, more accurate, and more research precise data. The author would like to express gratitude to the Central Java Highway Department and her friends who have provided support in the form of data, enabling the smooth execution of the research.

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