CITIZEN: Jurnal Ilmiah Multidisiplin Indonesia
Vol 2, No. 5, 2022
ISSN: 2807-5994
https://journal.das-institute.com/index.php/citizen-journal

Geometric Design of Upper Cisokan Hydroelectric Power Plant Access Road with AutoCAD® Civil 3D (STA 3+000 - STA. 4+800)

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DOI: 10.53866/jimi.v2i5.200

Abstract
The project to upgrade the access road to the Cisokan hydroelectric power plant and handle landslides is known as the Upper Cisokan Hydroelectric Power Plant Access Road Project. This access road has been a plan and completed build by PT. Pembangunan Perumahan (Persero) Tbk in 2019. There are several geometric alignments of the road with sharp curves. In this paper, the author intends to make a geometric plan for a new road in an area of STA. 3+000 – STA. 4+800. Planning is carried out using the AutoCAD® Civil 3D application for more effective and efficient results. The research method used is the Qualitative Method. The data source is obtained from the project data of the contractor, an access road to the Upper Cisokan hydroelectric power plant, and a reference to the Road Geometric Design Guidelines in 2021. Contour data is obtained from Google Earth® and processed using the Global Mapper® application. Planning is carried out by determining the design criteria of the road under review. Then the design criteria are used as a reference in making horizontal alignments, vertical alignments, superelevation, road assemblies, and corridor planning. The results of the planning obtained seven curves of horizontal and five curves of vertical. Furthermore, the AutoCAD® Civil 3D application is more effective and efficient because the process is relatively fast and easy, and changes to an item can be directly connected to all items.

Keywords: Access Road, AutoCAD® Civil 3D, Horizontal Alignment, Vertical Alignment

1. Introduction

Highways, arterial roads, collector roads, and local roads can all be classified using the basic functional classification scheme for roads (Hui, Saxe, Roorda, Hess, & Miller, 2018). The four types of roads have their properties, traffic movements, and road transport. As with local roads serving short-distance freight, the average speed is low, and the number of driveways is not restricted. These local roads are differentiated into primary and secondary ones (Shamin & Demak, 2019). It is said that roads have a role in the distribution of goods and services of national activities with environmental activities (Rahayu, Febrianti, & Khadafi, 2021). Additionally, it is crucial to implement energy resource distribution for society.

Development is significant to be carried out as a form of effort to increase economic productivity in a country (Rifai, Surgiarti, Isradi, & Mufhidin, 2021). Indonesia is one of the Southeast Asia regions that has problems with the energy crisis (Erdiwansyah, et al., 2021). So that in handling and efforts to meet society's need for energy, it is necessary to build energy plants to support the energy supply. The availability of energy plants, especially electrical energy in Indonesia, still needs to be improved (Sugiharto, 2018) . PT. PLN (Persero) is constructing power plant projects across the country as part of the aim to deliver electrical energy. The construction of the Upper Cisokan hydroelectric power plant is one of these initiatives. The construction of an access road to the area certainly accompanies this hydroelectric power plant construction project.

The adequate availability of infrastructure provided by the government is a determinant of the productivity of a country (Rifai, Latief, & Rianti, 2018). For example, the construction project of the access road to the Upper Cisokan hydroelectric power plant improves transportation access and handles landslides in the area. The access road that stretches for 27 km crosses two districts with five rural areas, including Sarinagen Village, Sirnagalih Village, Cijambu Village (Cipongkor District), Cibitung Village, Sukaresmi Village (Rongga District) West Bandung Regency (Choir, et al., 2018).

Today's geometric road planning requires a quick and precise planning process. The use of technology in the form of computer applications can be carried out to fulfill this. One of them is the AutoCAD® Civil 3D application. This application aims to make the planning process more effective and efficient in terms of cost, time, and resources (Pandey, Atul, & Bajpai, 2019) . AutoCAD® Civil 3D uses the concept of Building Information Modeling (BIM), which can present a more realistic planning design physically and functionally (Raji, Zava, Jirgba, & Osunkunle, 2017).

This access road has been the plan and completed build by PT. Pembangunan Perumahan (Persero) Tbk in 2019. There are several geometric alignments of the road with sharp curves. In this paper, the author intends to make a geometric plan for a new road in an area of STA. 3+000 – STA. 4+800. Geometric planning is carried out using the AutoCAD® Civil 3D application and concerning the Road Design Standard of Indonesia 2021. This software aims to get more effective and efficient planning results. Without consideration of the project's construction cost, the road's geometric planning will be made up of horizontal alignment, vertical alignment, superelevation, assemblies, and corridor planning.

2. Literature Study

2.1 Road Geometric Planning

Road design is an essential part of transport engineering. One of the main aspects of street design is geometric planning which focuses on placing roads on topographic maps (Kazemiroodsari & Kamat, 2021). Geometric planning is part of road planning that focuses on the physical shape so that the primary function of the planned road can be fulfilled. The primary function is to provide optimum service in traffic flow and access from one place to another. The geometric layout of the road has three fundamental parts: horizontal alignment, vertical alignment, and cross-section. The three essential parts, when combined, will provide a three-dimensional format for a road (Gaikawad & Ghodmare, 2020).

Horizontal alignment is a collection of points that form a straight line (tangent) or a curve (arch) as a projection of the axis of the road in the horizontal plane. The geometric design of the road on the curved part is intended to compensate for the centrifugal force on the vehicle with speed to stay on the actual path (Arrang, Tarru, Alik, Basri, & Miri, 2022) . Horizontal alignment has three curves: full circle, spiral circle spiral, and spiral-spiral. A full circle (FC) is an arch that takes the form of a full circle of arcs. Only some curves can be entirely circled. Only curves with a large radius are allowed. A Spiral Circle Spiral (SCS) is a curve consisting of one circular arch and two spiral curves. A transition curve connects the straight and circular parts. That is, before and after the curve in the form of a circular arc. A Spiral-spiral (SS) is a curve without a circular or curved arc consisting of two spiral arches (Hasan, Firdaus, Sundara, & Astor, 2020).

Vertical alignment is the intersection of a vertical plane with the plane of the road pavement surface through the axis of the road for a bidirectional two-lane road or through the inner edge of each pavement for a road with a median (Putri, Nanda, & Aminsyah, 2021). Vertical alignment consists of a straight section and a curved section reviewed from the starting point of planning. The vertical curve can be flattened or peaked, and the straight part can be a positive ramp of the ascent or a negative ramp descent.

In addition to calculations and analysis, the geometric design of the road included adjustments to the safety and level of service required in a specific terrain. It includes road elements seen by road users and aims to align the road on the right of the permitted road, ensuring the required speed of operation, safety, and quality of driving (Aryal, 2020). Safety is also the primary goal of the transport system, which is to provide security and efficient movement of people and goods. One of the tools to improve road safety is design consistency and its impact on road safety (Al-Sahili & Dwaikat, 2019).

2.2 Road Classification

Roads can be divided into four categories based on their function. The arterial road is a public road that serves as the main transportation with the characteristics of long-distance travel and high average speed. The number of entrances to this road is very effectively limited. Collector Road is a public road that serves transportation with medium-distance travel, moderate average speed, and a limited number of driveways. A local road is a public road that serves local transport with short-distance travel, low average speed, and available driveways. Finally, an environmental road is a public road that serves local transport with short-distance travel, low average speed, and a local driveway (Anwari, 2022).

Roads are classified into five types based on their status: national roads, provincial roads, county roads, city roads, and village roads. National roads are collector arterial roads in the primary road network system connecting provincial capitals and national strategic roads. Provincial roads are collector roads in the primary road network system that connect the provincial capital with the regency/city or between the capital of the regency/city and the strategic road of the province. District roads are local roads in the primary road network system that connect the district capital and the subdistrict capital, between the subdistrict capitals, with local activity centers. City roads are public roads in the secondary road network system that connect service centers within the city, connect service centers with parcels, connect between parcels, and connect between residential centers within the city. Meanwhile, village roads are public roads connecting areas between settlements in the village and environmental roads (Widari, Akbar, & Fajar, 2021).

2.3 AutoCAD® Civil 3D

AutoCAD Civil 3D® is a Building Information Modeling (BIM) system application that can help reduce the time to design, analyze, and implement changes. AutoCAD® Civil 3D performs fast and intelligent design programs. The program is built on a 3D model that updates the design of dynamically related civilian elements as they change. The program can link design and documentation, thus helping to increase productivity and provide higher quality in construction design. This program is due to changes to design elements captured in the documentation and minimizes manual updates (Raji, Zava, Jirgba, & Osunkunle, 2017).

AutoCAD® Civil 3D is a software engineering used to plan and design building construction projects, road engineering, and water work engineering, including the construction of dams, ports, canals, and embankments. In designing, AutoCAD® Civil 3D significantly reduces the time required to implement design changes and evaluate some situations. Changes are made in one place and can update the entire project. This can undoubtedly make the completion of a project faster, wiser, and more accurate (Chakole & Wadhai, 2022).
The software provides clarity and saves time and effort for users. This capability of AutoCAD® Civil 3D eliminates the main drawbacks of a complicated, time-consuming, and highly error-prone manual design approach. AutoCAD® Civil-3D is very well used for design and drafting, dramatically reduces the time required to change the tool's design, and evaluates various situations. Changes made in one place immediately update the entire project, helping projects much earlier, more competent, and more accurate (Mandal, Pawade, & Sandel, 2019).

This AutoCAD® Civil 3D application can be used to create 3D models of projects and help adapt for small and large-scale projects. To carry out the design of Civil 3D software, a digital terrain model (DTM) is created from the contours covering the road. Then, points taken from the road alignment are transferred to the DTM. The points and road alignment are then combined (Turk, 2019).

3. Methodology

The research method used in this paper is the Qualitative Method. The research data is obtained from in-depth understanding, theory development, and reality description. Data is one of the leading forces in compiling scientific research and modeling (Rifai, Hadiwardoyo, Correia, Pereira, & Cortez, 2015). The data sources required in this paper are obtained from the project data of PT. PP on the access road to the Upper Cisokan hydroelectric power plant construction project. The data is in the form of road planning drawings (STA. 3+000 – STA. 4+800). Contour data is obtained from Google Earth® and processed using the Global Mapper® application. The observation location of this paper is located in West Bandung regency, which crosses two sub-districts, as shown in the location map in figure 1.

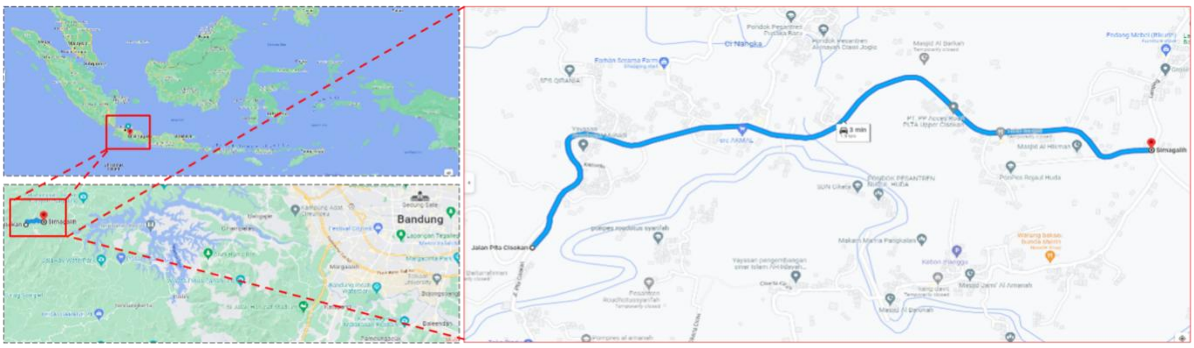

Figure 1. Location Map of Upper Cisokan Hydroelectric Power Plant Access Road

Systematic scientific research must identify the right problem (Rifai, Hadiwardoyo, Correia, & Pereira, 2016). For example, the geometric planning of the access road to the Upper Cisokan hydropower plant has been made and implemented, but the author sees some sharp geometric curves. So that, to get better results, in this paper, a re-planning was carried out using the AutoCAD® Civil 3D application concerning the Road Design Standard of Indonesia (PDGJ) in 2021. The stages in geometric road planning using the AutoCAD® Civil 3D application include setting the coordinate system in AutoCAD® Civil 3D, entering contour data, creating a surface, creating horizontal alignment, creating vertical alignment, creating superelevation, returning the calculation results of vertical alignment and horizontal alignment (Putri, Nanda, & Aminsyah, 2021).

4. Result and Discussion

Geometric planning of the access road to the Upper Cisokan hydroelectric power plant STA. 3+000 – STA. 4+800 uses an application that integrates with BIM. The application used is the AutoCAD® Civil 3D 2019 Metric version with the main features, as seen in figure 2.

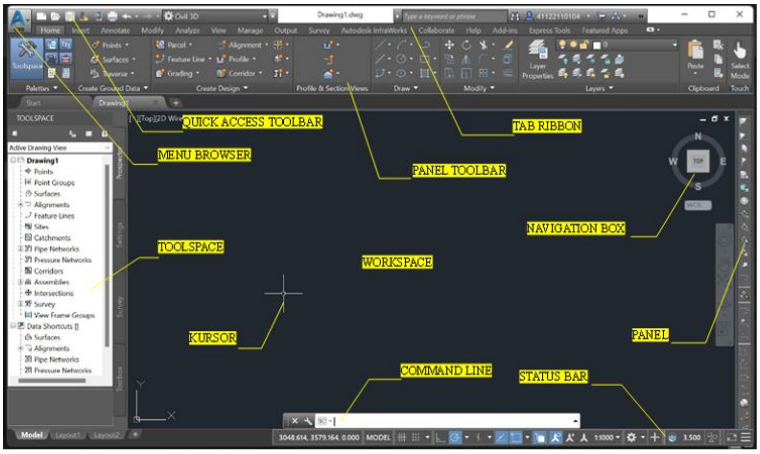

Figure 2. AutoCAD Civil 3D® 2019 Metric work area display

4.1 Planning Criteria

In this paper, some planning criteria specified in geometric road planning include road function classification, terrain class classification, vehicles, road parameters, and plan speed. For example, the access road to the Upper Cisokan hydroelectric power plant is classified as a primary local road with the status of a village road. Type road is a 2-way and 2-lane (2/2 TB) with a road body width of 8 meters. The road surface has a slope of 10-25%, so it can be said to be a road with a hill terrain class. Based on Table 5-1 in PDGJ 2021 page 41, the plan speed for these road types ranges from 20-50 km/h. In this planning, we used the planned speed of 40 km/h. Plan vehicles that pass by are commercial vehicle types (class 5a-7c3).

In the geometric planning of roads, it is necessary to know the datum information of the planned work area. Using the Google Earth® application, information was obtained that the Upper Cisokan hydroelectric power plant access road is included in the 48S datum. Furthermore, contour data collection is carried out through the National Digital Elevation Model (DEMNAS). In importing DEMNAS data, we need the help of the Global Mapper® application. The data is then used in creating surfaces in the AutoCAD® Civil 3D application.

4.2 Horizontal Alignment

Re-planning of the Upper Cisokan access road area of STA. 3+000 – STA. 4+800 made a change of stationing to planning stationing. The planned length of the road trace stretches as far as 1.53 km starting from STA. 0+000 until STA. 1+531. Road planning in the AutoCAD® Civil 3D application is divided into 7 Points of Interest (PI) which can be seen in figure 3.

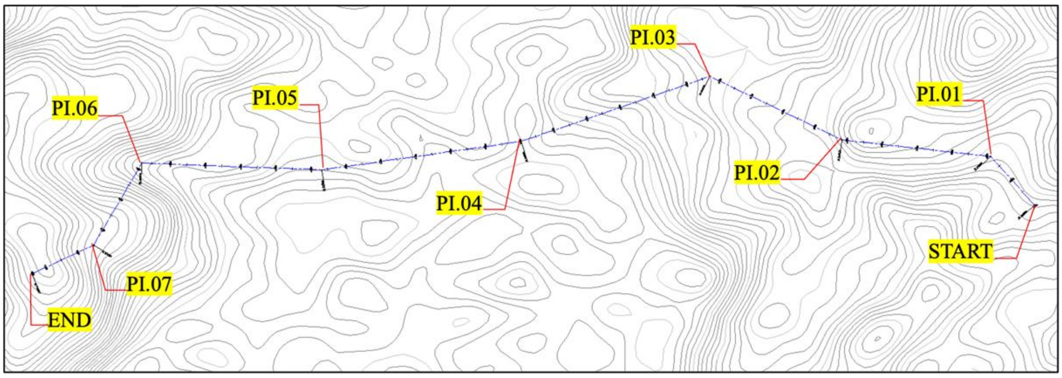

Figure 3. Road Planning Trace

Horizontal curve planning is created using the "Alignment" tool by selecting "Alignment Creation Tools." Furthermore, in the "Alignment Layout Tools" section, "Tangent-Tangent (with curves)" is selected, then create a horizontal alignment according to the planned PI. From the planning results, there are seven horizontal curves with a radius of 200 m which can be seen in figure 4.

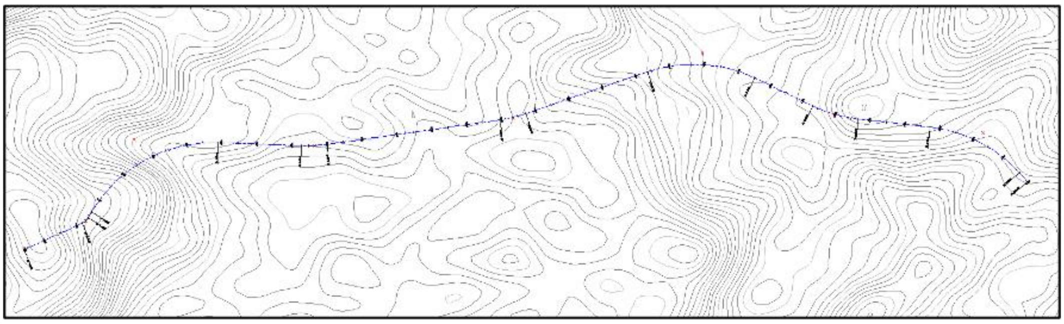

Figure 4. Horizontal Alignment Planning

4.3 Vertical Alignment

Before planning a vertical alignment, it is necessary to know the existing profile of the planned alignment. This determines the high and low profiles along the planning trace. The existing profile of the planned alignment appears as part of the results of the horizontal alignment projection on the planning of the Upper Cisokan hydroelectric power plant access road. In AutoCAD® Civil 3D applications, the existing profile of the planned alignment can be raised through the "Profile" tool and then select "Create Surface Profile". In the "Create Profile from Surface" section, select the alignment and surface created in the horizontal alignment planning, then select "Add". The existing alignment profile will appear as in the example in STA. 0+000 – STA. 0+500 in figure 5.

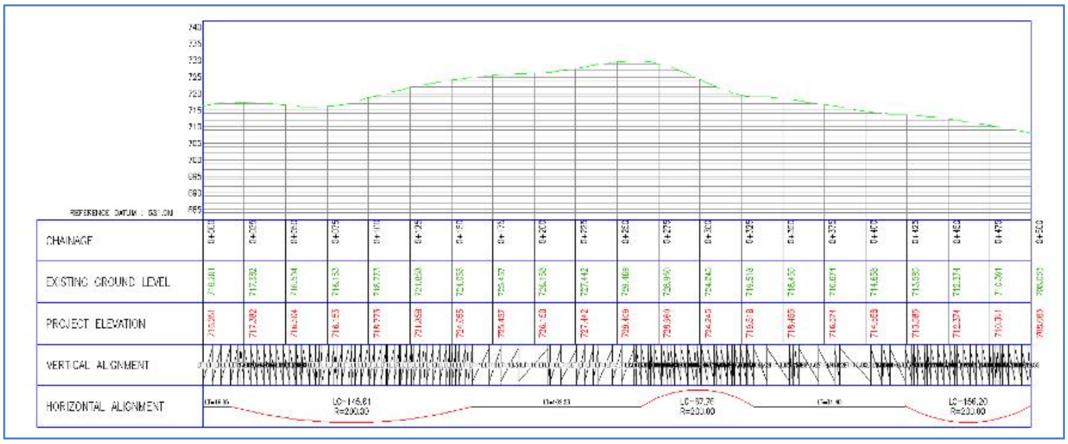

Figure 5. Existing Plan Alignment Profile

The vertical alignment planning design profile is made concerning the original soil existing profile of

CITIZEN: Jurnal Ilmiah Multidisiplin Indonesia
Vol 2, No. 5, 2022
ISSN: 2807-5994
https://journal.das-institute.com/index.php/citizen-journal

the planned alignment. Vertical alignment planning is good if it follows the contours of the existing profile or the original ground level. That is because it can reduce the volume of cut and fill work to be carried out. This planning has five verticals consisting of 1 convex curve (Crest) and four concave curves (Sag). An example of the results of vertical alignment planning in STA. 0+ 000 – STA. 0+500 can be seen in Figure 6.

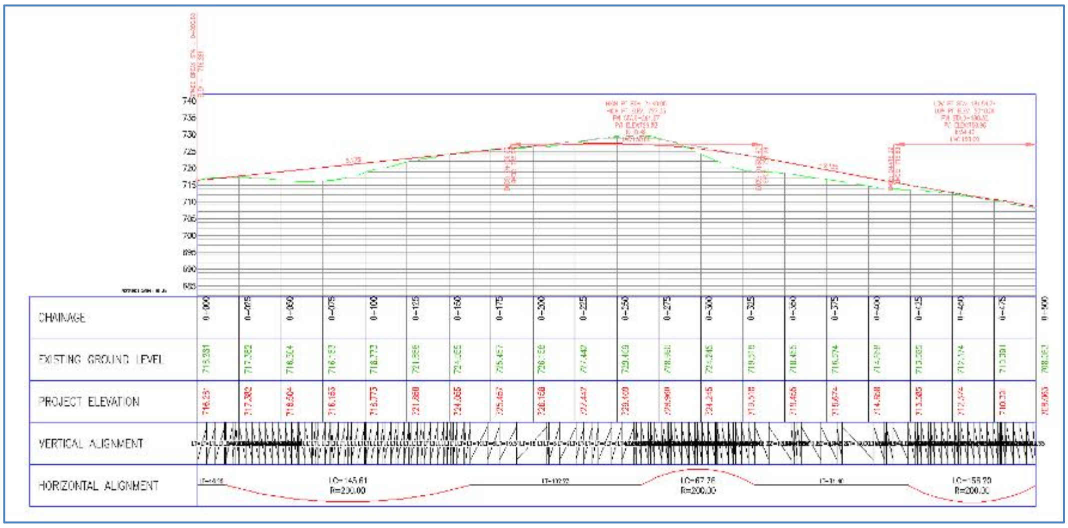

Figure 6. Vertical Alignment Planning Design

4.4 Superelevation

An example of the results of superelevation calculations on planning the Upper Cisokan hydroelectric power plant access road is shown for STA. 0+200 – STA. 0+400 is a diagram that can be seen in **figure 7.** This diagram can be displayed in the AutoCAD® Civil 3D application on the "Superelevation" menu by selecting "*Calculate/Edit Superelevation*".

Figure 7. Superelevation Diagram

4.5 Assembly

Assembly planning needs to be done before the creation of road corridors. This stage can be created in the AutoCAD ®Civil 3D application on the "Assembly" menu, then by selecting "Create Assembly." Then adjust the road planning data and include other sub-assemblies such as the shoulder of the road (Shoulder), channel (Trench), and daylight bench on the Assembly menu. In this planning, a road lane width of 4 m with a slope of 2% is made. The road base layer is 0.1 m thick, with the first pavement layer 0.3 m thick and the second layer 0.4 m. The shoulder of the planned road is 1 m wide with the same number and thickness of road layers as the main road. Further, the planning of the channel is made with the type "Ditch" with a width and depth of 1 m. The results of the road assembly planning can be seen in figure 8.

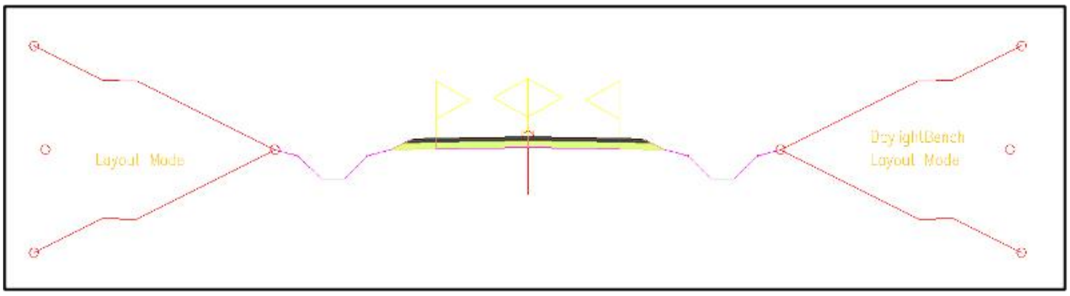

Figure 8. Assembly Planning Design

4.6 Corridor Planning

In the AutoCAD® Civil 3D application, the planned street corridor can appear on the "Alignment" menu, then by selecting the "Corridor" tab and selecting "OK." Next, a warning box will appear, then select "Rebuild the Corridor." Then a picture of the corridor of the planned road will appear. One example of the corridor part of the planned road can be seen in figure 9.

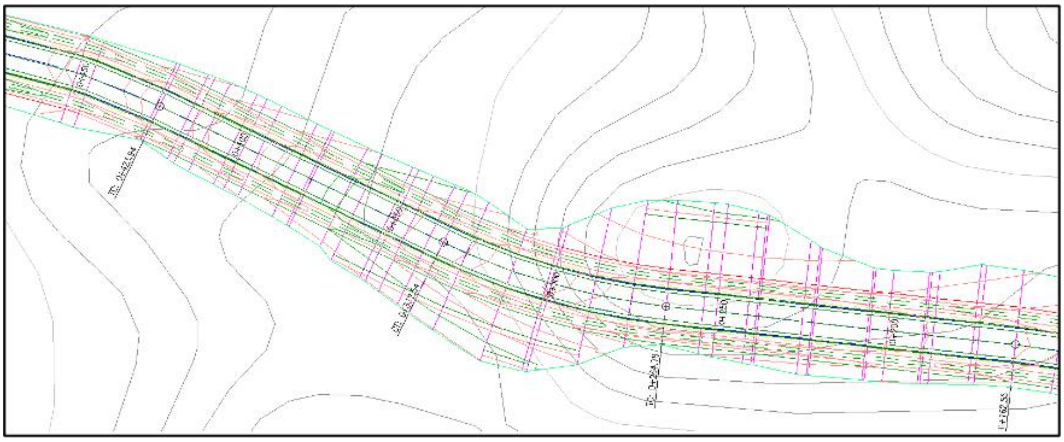

Figure 9. Corridor Planning Section

5. Conclusion

Results of re-planning and data processing on the planning of the Upper Cisokan hydroelectric power plant access road in the area STA. 3+000 - STA. 4+800, some conclusions can be drawn. Re-planning trace changed STA plan to STA. 0+000 – STA. 1+531. Horizontal alignment planning obtained seven curves with a radius of 200 m. The results of vertical alignment planning obtained five vertical curves consisting of 1 convex curve (Crest) and four concave curves (Sag). Furthermore, in using AutoCAD® Civil 3D applications in geometric road planning, it can be said to be more effective and efficient in various ways. This process is relatively fast and easy, and changes to an item can be directly connected to other items.

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