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Highway Geometric Design Using Civil 3D

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Abstract: This project explores how AutoCAD Civil 3D can transform highway design by making it faster, more accurate, and better suited to modern needs. Highways are complex structures that need precise planning to ensure they're safe, efficient, and comfortable for drivers. Traditional methods of highway design—often done by hand—are time-consuming, leave room for error, and make even small adjustments difficult once the design is set. Civil 3D, on the other hand, offers a solution by automating much of the design process, allowing for easy adjustments, and generating 3D models that help engineers visualize the final result from every angle. Our approach in this project involves gathering real-world data, setting up road alignments, defining cross-sections, and modeling the entire corridor in Civil 3D. The software's tools help us meet critical safety standards, optimize the materials used, and design with minimal environmental impact. Ultimately, Civil 3D proves to be an invaluable tool for highway design, offering a streamlined and more effective alternative to manual methods.

***Index Terms* -** Highway geometric design, AutoCAD Civil 3D, corridor modeling, horizontal alignment, vertical profile, cross-sections, cut and fill.

I. Introduction

The development of a constructive road transport system is the primary purpose of any country. The improvement of existing road network system is also essential as the traffic on urban and rural highways touches to saturation level over a given period of time. The road development projects being highly capital intensive involve very high degree of recognition by the project authorities as well as by the consultants, engineers and contractors. Any type of mistake may result in wastage of millions, which could have been avoided. Normally the alignment and the pavement construction decide the cost of a highway project and for this job the best experienced manpower and the best available tools must be deployed. Today in extremely competitive and sensitive business environment a timely preparation of road construction and reconstruction projects depends on modern computer-based facilities. AutoCAD Civil 3D design software that are widely used in the world over in the road projects.

Software description

AutoCAD Civil 3D is a civil engineering design and documentation tool developed by Autodesk for civil engineers and other professionals to plan, design, and manage civil engineering projects. Civil 3D allows to create three dimensional (3D) models of land, water, or transportation features while maintaining dynamic relationships to source data such as grading objects, breaklines, contours, and corridors. Individuals who are currently using AutoCAD or plan on learning AutoCAD will inherit many benefits of using Civil 3D. Civil 3D was originally created to be an add-on for AutoCAD but as its popularity and demand grew, it was further evolved and developed into a stand-alone product built on the AutoCAD platform. Civil 3D offers a familiar design environment and many AutoCAD-compatible shortcuts and with true DWG (drawing) file support, Civil 3D allows you to store and share design data with existing AutoCAD users.

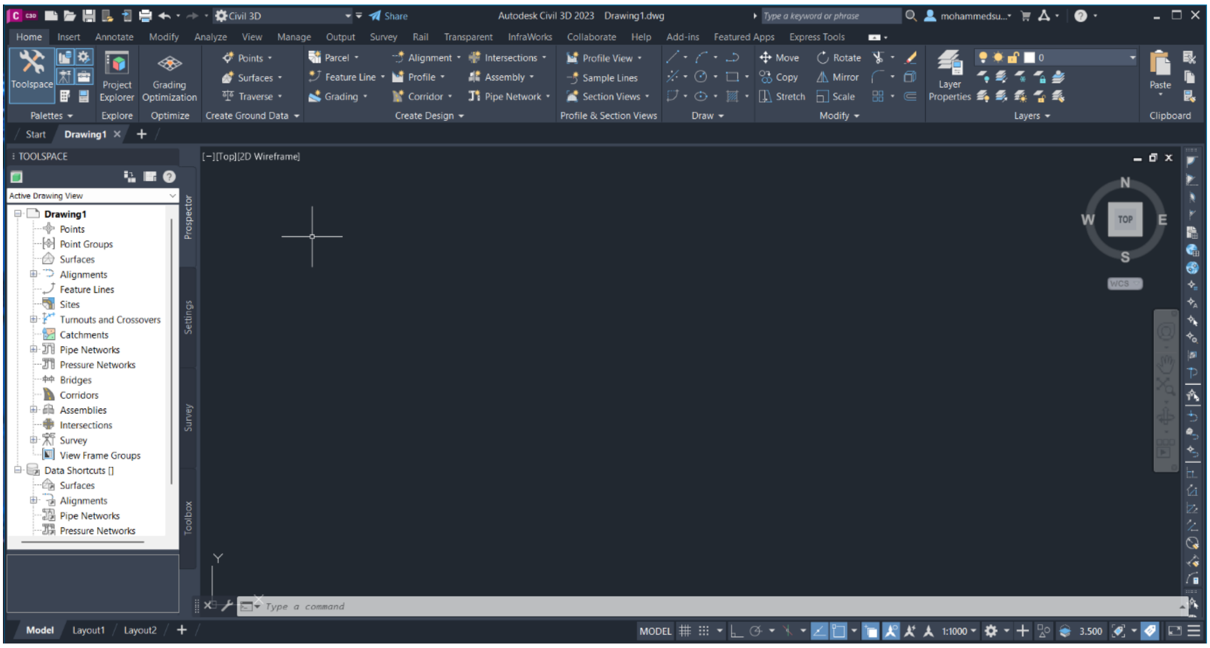


Fig.1 Software Interface

II. LITERATURE REVIEW

1. Chaudhari et al. explored the relationship between geometric inconsistencies and accident risks on two-lane rural highways in hilly terrains. Their research underscored that abrupt changes in alignment and inadequate signage contribute significantly to speed variation and driver discomfort. They proposed integrating driver behavior analytics and intelligent traffic-calming features like rumble strips to enhance safety.
2. Eliseev et al. examined how 3D modeling technologies have revolutionized road safety research and urban traffic management. By employing tools such as AutoCAD Civil 3D, InfraWorks, and Digital Twin systems, they enabled realistic simulations for infrastructure assessment and accident prediction. The study emphasized the role of machine learning and predictive mapping in identifying accident-prone zones and optimizing geometric layouts before construction.
3. Gautam et al. demonstrated the utility of Civil 3D in geometric optimization during the redesign of the SH-205 ring road near Solapur City. Their findings show that incorporating digital tools enhances design accuracy, reduces long-term maintenance costs, and improves overall traffic safety by enabling efficient layout planning and real-time data integration.
4. Panulinova et al. focused on the development of 3D digital terrain models using point cloud data. Their research emphasized the use of BIM and AutoCAD Civil 3D in producing parametric roadway models, improving stakeholder collaboration, and reducing design errors. The study showed how integrating environmental data and construction parameters can lead to sustainable design outcomes.
5. Saed and Ewadh utilized AutoCAD Civil 3D and IHSDM to evaluate crash frequencies at signalized intersections. By importing 3D road geometries into crash prediction software, they could assess the distribution of collision types and identify hazardous junctions. Their work highlights the importance of predictive safety analysis in early design stages for urban roads.
6. Said et al. employed artificial neural networks (ANNs) to develop speed prediction models for elevated urban arterials. Their study emphasized that urban roads require complex modeling due to varied influences such as intersections and road elevation. They found that ANN-based models outperformed traditional regression models in predicting operating speeds, suggesting a need for AI-driven design tools.
7. Tanoli et al. focused on integrating 3D design models with machine-guidance systems in earthwork operations. Their findings support the use of digital terrain models and GPS-enabled machinery to improve construction accuracy, minimize rework, and reduce operational delays. The study reinforced the value of 3D modeling in real-time monitoring and quality control.

III. PROJECT LOCATION

The selected project site is a 2.748 km section of SH-3, extending from Kudappanamoodu to Vazhichal Junction. The chainage station ranges from start point : 0+000.00 and end point : 2+748.30. This road is a crucial link that connects key locations such as Amboory, Nedumangadu, and Neyyar Dam, serving as an important route for local and regional transportation.

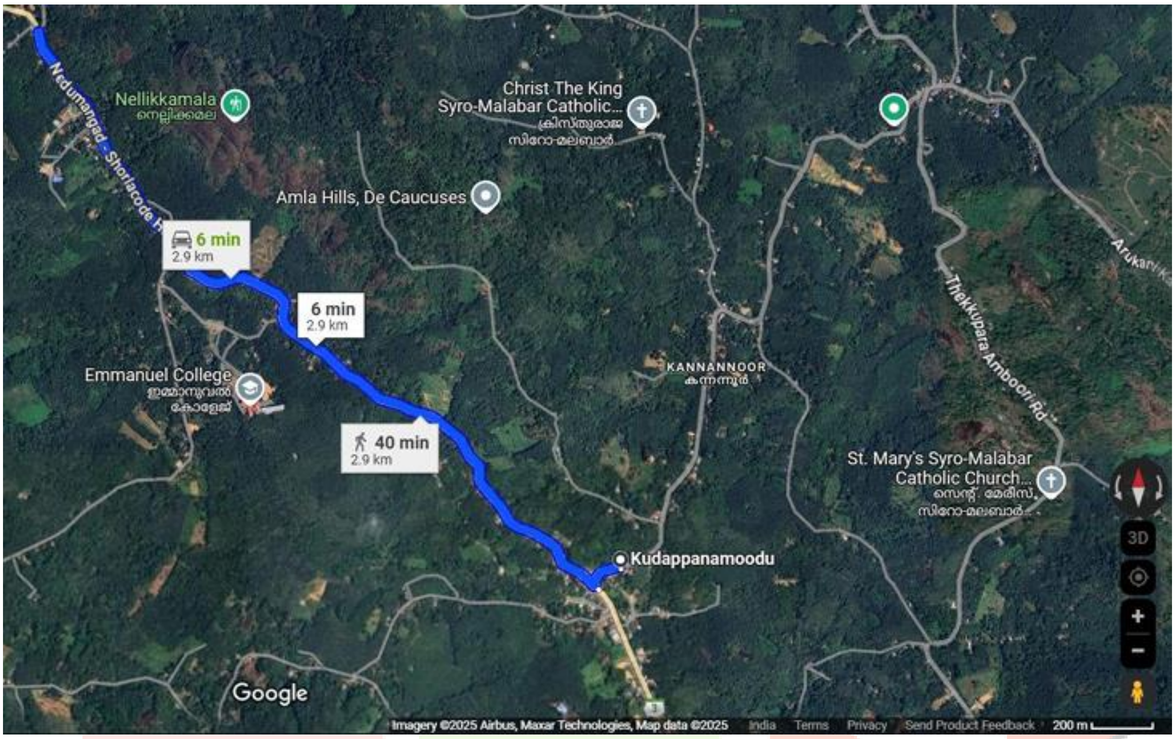


Fig.2 Project Location (Source: Google Map)

IV. OBJECTIVES OF STUDY

- To widening the existing road of Kudappanamoodu – Vazhichal Junction from 6m to 12m.
- To create the Horizontal Alignment and the Vertical Profile of the newly designed road using Civil 3D.
- To create the Cut and Fill volume table for balancing the earthwork.
- To Utilize Civil 3D tools to streamline design processes and improve project efficiency.

V. METHODOLOGY

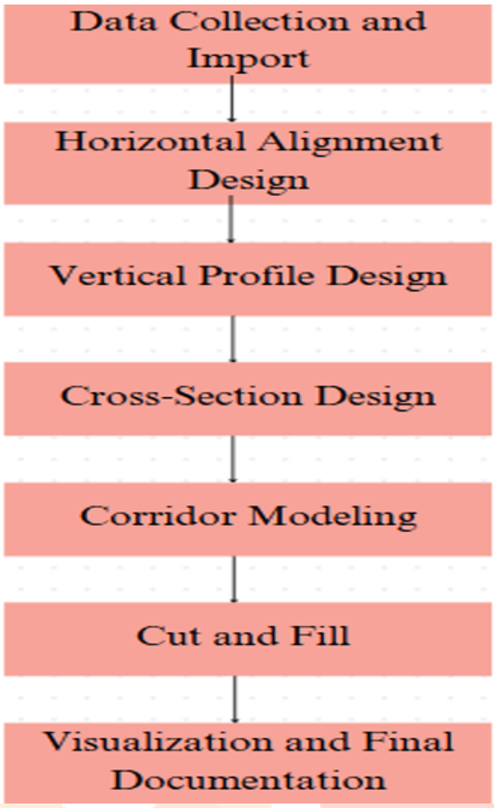


Fig.3 Flowchart of Methodology

5.1 Data Collection and Import

Gathering essential information about the existing terrain, road conditions, drainage features and surrounding environment to ensure precise geometric design using Civil 3D. Topographic and road condition data were collected via PWD survey and LiDAR. This data was imported into Civil 3D using LandXML to create accurate terrain models for design.

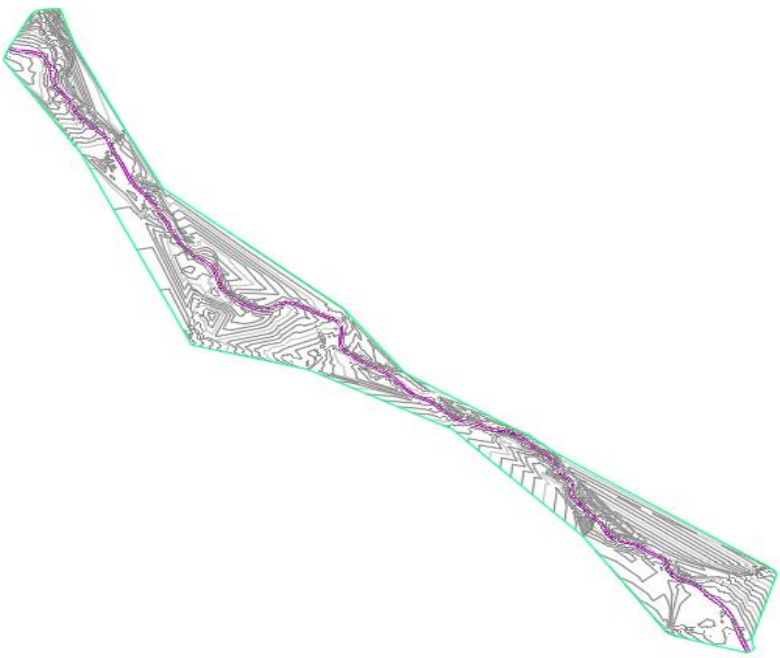


Fig.4 Existing Surface

5.2 Horizontal Alignment

The horizontal alignment of a highway is a critical component that determines the layout of the road in the plan view. It consists of straight sections (tangents), horizontal curves, and transition curves, which together ensure safe and efficient vehicle movement. Properly designed horizontal alignment enhances driver comfort, reduces accident risks, and minimizes construction costs by optimizing land use and earthwork operations.

Horizontal alignment was designed considering a 50 km/h design speed, terrain constraints, and safety standards. Civil 3D was used to lay out curves, transitions, and apply superelevation.

Table 1 Design Criteria

DESIGN PARAMETER	VALUE	IRC CODE
Design Speed	50 km/hr	IRC:SP:48-1998
Superelevation	10 %	IRC:SP:48-1998
Stopping Sight Distance (SSD)	60 m	IRC:SP:48-1998
Roadway Width	12 m	IRC:SP:23-1993
Carriageway Width	7 m	IRC:SP:48-1998
Shoulder Width	1.8 m	IRC:SP:48-1998

Table 2 Superelevation Values

Superelevation Curve	Start Station	End Station	Length	Overlap	Left Outside Shoulder	Left Outside Lane	Right Outside Lane	Right Outside Shoul...
Curve.1								
Transition In Region	-0+026.96...	0+047.29...	74.250m					
End Normal Shoulder	-0+026.96...				-5.00%	-2.00%	-2.00%	-5.00%
Runout	-0+002.21...	0+014.29...	16.500m					
End Normal Crown	-0+002.21...				-5.00%	-2.00%	-2.00%	-2.00%
Level Crown	0+014.29m				-5.00%	-2.00%	0.00%	0.00%
Runoff	0+014.29m	0+047.29...	33.000m					
Level Crown	0+014.29m				-5.00%	-2.00%	0.00%	0.00%
Reverse Crown	0+030.79m				-5.00%	-2.00%	2.00%	2.00%
Begin Full Super	0+047.29m			⚠	-5.00%	-4.00%	4.00%	4.00%
Begin Curve	0+047.29m			⚠				
Transition Out Region	0+054.25m	0+128.50...	74.250m					
Runoff	0+054.25m	0+087.25...	33.000m					
End Full Super	0+054.25m			⚠	-5.00%	-4.00%	4.00%	4.00%
End Curve	0+054.25m			⚠				
Reverse Crown	0+070.75m			⚠	-5.00%	-2.00%	2.00%	2.00%
Level Crown	0+087.25m			⚠	-5.00%	-2.00%	0.00%	0.00%
Runout	0+087.25m	0+103.75...	16.500m					
Level Crown	0+087.25m			⚠	-5.00%	-2.00%	0.00%	0.00%
Begin Normal Cro...	0+103.75m			⚠	-5.00%	-2.00%	-2.00%	-2.00%
Begin Normal Shoulder	0+128.50m			⚠	-5.00%	-2.00%	-2.00%	-5.00%

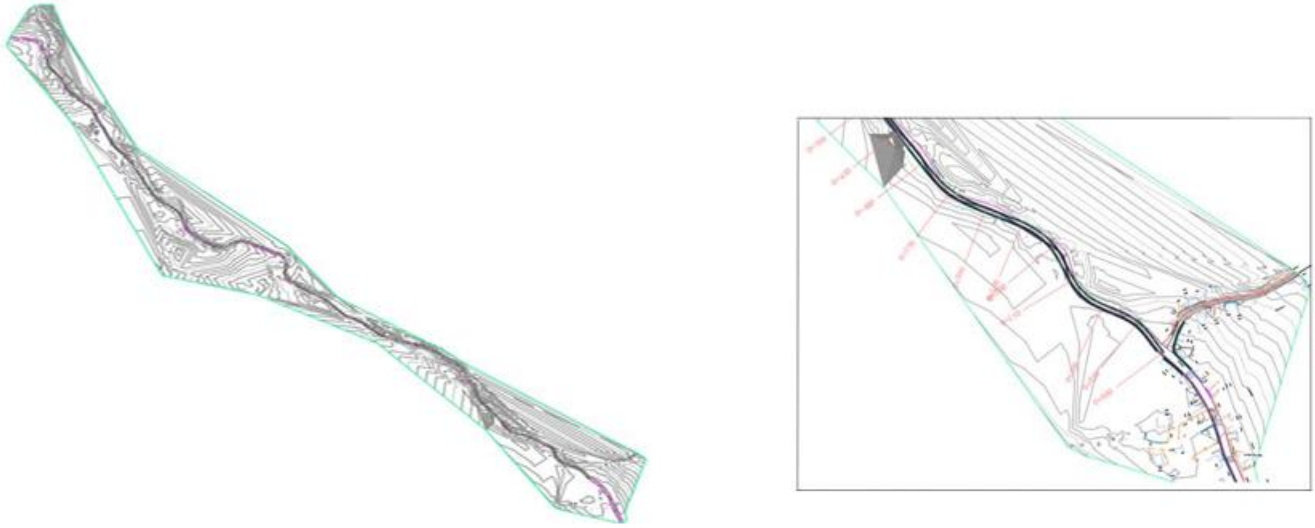


Fig.5 Horizontal Alignment and Zoomed Image with Alignment

5.3 Vertical Alignment

The vertical alignment of a highway consists of gradients (slopes) and vertical curves that determine the road's elevation changes. This aspect of the design is crucial for ensuring smooth vehicle movement, maintaining driver comfort, and minimizing excessive earthwork. Proper vertical alignment helps reduce fuel consumption, improve drainage, and enhance road safety.
Vertical profiles were developed using crest and sag curves to ensure smooth elevation transitions and driver comfort.

Table 3 K Values

DESIGN PARAMETER	VALUE	IRC CODE
Minimum K for Crest curve	7	IRC:SP:23-1993
Minimum K for Sag curve	18	IRC:SP:20 -2002

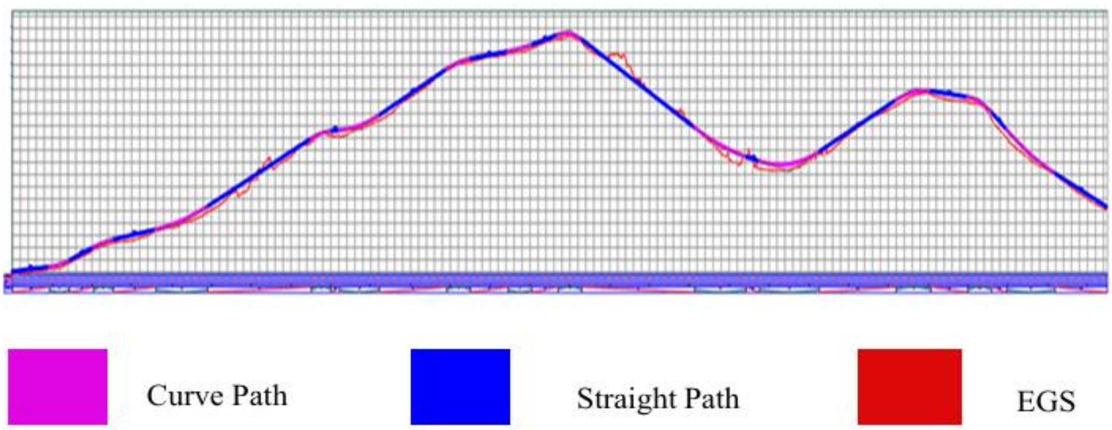


Fig.6 Vertical Profile

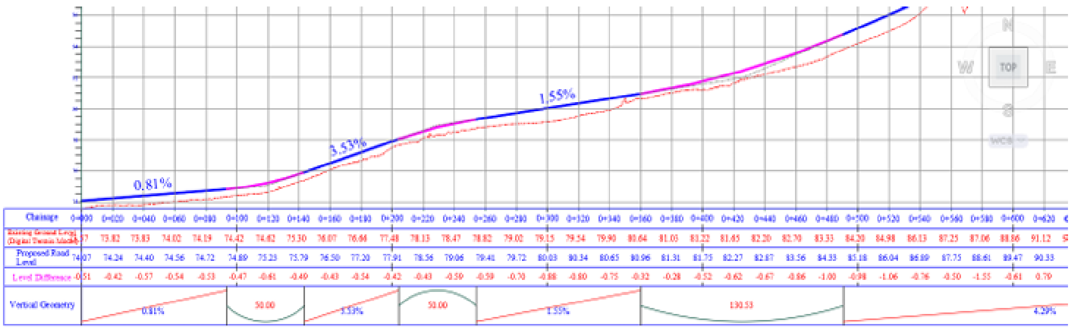


Fig.7 Details of Vertical Profile

5.4 Cross-section (Assembly)

The cross-section design of a highway defines the structural layout of the road, including lane widths, shoulders, medians, and drainage features. Proper cross section design ensures road safety, efficient traffic movement, and effective stormwater management. A primary road complete section assembly is used for this analysis in the development of a road corridor.

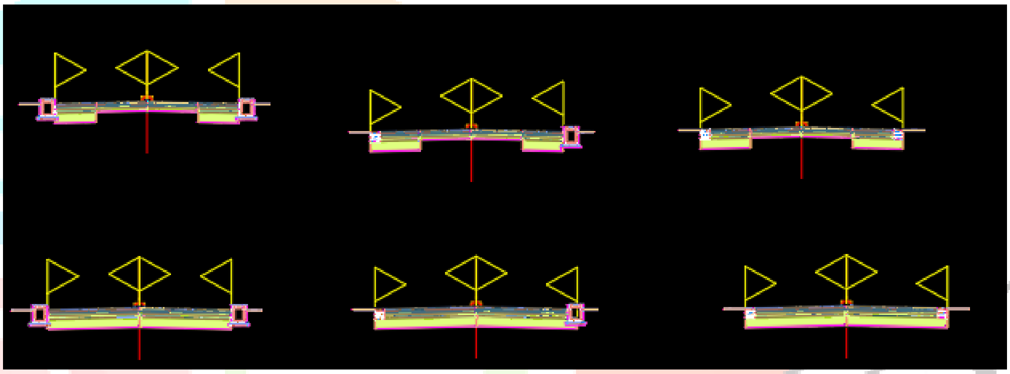


Fig.8 Assemblies

5.5 Corridor Modeling

Corridor modelling is a crucial step in highway design that integrates horizontal and vertical alignments with cross-section templates to create a 3D representation of the road. This process allows for the visualization and optimization of road geometry, ensuring a well-balanced design that meets engineering standards while minimizing construction costs.

Table 4 Corridor Properties

Corridor Properties - Corridor - KUDAPPANAMOODU

Information | Parameters | Codes | Feature Lines | Surfaces | Boundaries | Slope Patterns

Add Baseline | Set all Frequencies | Set all Targets

Name	Horizont...	Vertical ...	Assembly	Start Station	End Station	Frequency	Target	Overrid
BL - Alignment -50 k...	Alignme...	Design p...		0+000.00m	2+748.30m	...	...	
RG - TCS -I - (1)			TCS -I	0+000.00m	0+110.00m	20.00...	...	
RG - TCS -IV - (1)			TCS -IV	0+110.00m	0+450.00m	20.00...	...	
RG - TCS -I - (2)			TCS -I	0+450.00m	0+510.00m	20.00...	...	
RG - TCS -IV - (3)			TCS -IV	0+510.00m	0+550.00m	20.00...	...	
RG - TCS- V - (4)			TCS- V	0+550.00m	1+010.00m	20.00...	...	
RG - TCS II - (6)			TCS II	1+010.00m	1+050.00m	20.00...	...	
RG - TCS -I - (7)			TCS -I	1+050.00m	1+100.00m	20.00...	...	
RG - TCS -IV - (8)			TCS -IV	1+100.00m	1+150.00m	20.00...	...	
RG - TCS -I - (9)			TCS -I	1+150.00m	1+300.00m	20.00...	...	
RG - TCS -IV - (10)			TCS -IV	1+300.00m	1+390.00m	20.00...	...	
RG - TCS- V - (11)			TCS- V	1+390.00m	1+910.00m	20.00...	...	
RG - TCS II - (12)			TCS II	1+910.00m	1+950.00m	20.00...	...	
RG - TCS- V - (13)			TCS- V	1+950.00m	2+100.00m	20.00...	...	
RG - TCS II - (14)			TCS II	2+100.00m	2+150.00m	20.00...	...	
RG - TCS- V - (15)			TCS- V	2+150.00m	2+200.00m	20.00...	...	
RG - TCS -IV - (16)			TCS -IV	2+200.00m	2+240.00m	20.00...	...	
RG - TCS -I - (17)			TCS -I	2+240.00m	2+380.00m	20.00...	...	
RG - TCS -IV - (18)			TCS -IV	2+380.00m	2+460.00m	20.00...	...	
RG - TCS -VI - (19)			TCS -VI	2+460.00m	2+480.00m	20.00...	...	
RG - TCS -III - (20)			TCS -III	2+480.00m	2+550.00m	20.00...	...	
RG - TCS -VI - (21)			TCS -VI	2+550.00m	2+640.00m	20.00...	...	
RG - TCS -III - (22)			TCS -III	2+640.00m	2+748.30m	20.00...	...	

Select region from drawing

Lock Regions To: Geometry Locking

OK | Cancel | Apply

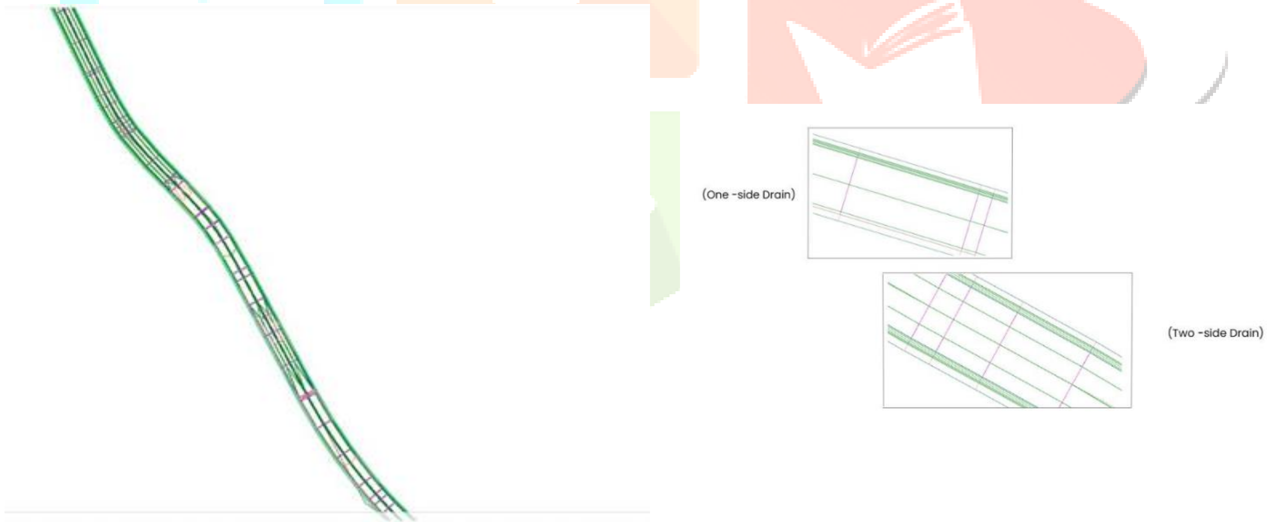
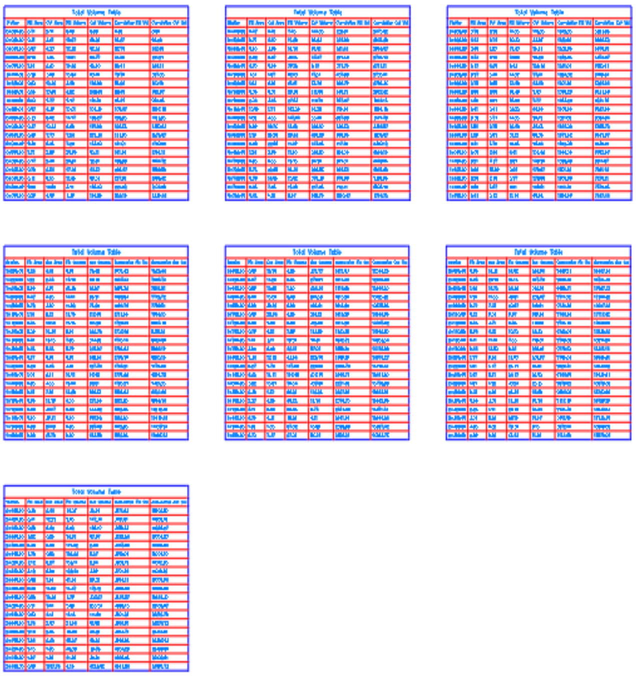


Fig.9 Corridor Layout and Zoomed Image

5.6 Cut and Fill

Cut and fill is a crucial aspect of highway geometric design, ensuring efficient earthwork management by balancing the volume of material excavated (cut) and placed as embankment (fill). Cut and fill volumes were calculated by comparing the design profile with the existing terrain. This process minimizes the need for importing or exporting excess material, reducing construction costs and environmental impact.



Total Volume Table

Station	Fill Area	Cut Area	Fill Volume	Cut Volume	Cumulative Fill Vol	Cumulative Cut Vol
0+000.00	0.71	2.91	0.00	0.00	0.00	0.00
0+020.00	0.31	3.61	10.27	65.20	10.27	65.20
0+040.00	0.97	4.53	12.52	82.28	22.79	147.48
0+060.00	0.98	3.55	18.61	83.77	41.40	231.25
0+080.00	1.01	2.63	19.42	62.90	60.83	294.15
0+100.00	0.58	3.69	15.94	63.15	76.76	357.30
0+120.00	0.23	12.32	8.49	155.90	85.26	513.19
0+140.00	0.16	13.68	4.22	249.48	89.48	762.67
0+160.00	0.43	5.77	5.97	191.39	95.45	954.06
0+180.00	0.87	4.56	13.01	103.30	108.47	1057.36
0+200.00	0.33	6.02	11.57	106.27	120.03	1163.63
0+220.00	0.37	13.33	6.65	197.00	126.68	1360.63
0+240.00	0.40	7.73	7.24	215.34	133.93	1575.97
0+260.00	0.36	5.45	7.29	133.03	141.21	1709.00
0+280.00	1.71	2.86	20.65	83.11	161.86	1792.11
0+300.00	0.97	2.40	26.81	52.61	188.68	1844.72
0+320.00	0.79	2.04	17.79	44.37	206.47	1889.09
0+340.00	0.31	6.10	11.45	80.33	217.91	1969.42
0+360.00	0.06	10.66	3.91	165.43	221.82	2134.85
0+380.00	0.26	9.06	3.36	195.59	225.18	2330.44

Table 5 Cut and Fill Calculation Table and Zoomed Table

5.7 Visualization and Documentation

Visualization and final documentation are essential steps in the highway design process, ensuring that the proposed design is accurately represented, analyzed, and validated before construction. Using Civil 3D, the visualization process provides a realistic representation of the road layout, while final documentation compiles all relevant data, drawings, and reports for project execution.

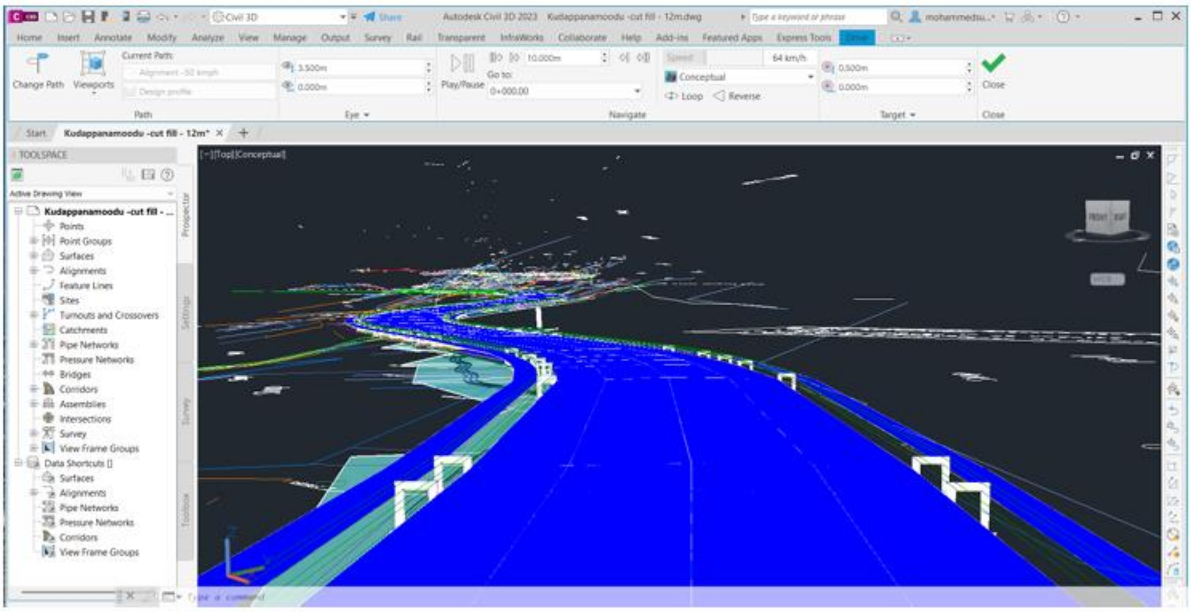


Fig.10 Perspective View

VI. CONCLUSION

- Civil 3D helps in designing the Horizontal and Vertical profile of the road within least time and labour spent.
- For road widening works Civil 3D can be used with good quality of precision. Here in this work, the design details for widening of the road from 6m to 12m was done.

- The main part of alignment design is the balancing line for cut and fill volume. If the cut and fill volume are not balancing, the entire work of selecting the alignment need to be done again. Civil 3D eases this part, as the software itself addresses this criteria in its design steps.
- With expertise, the entire works can be finished in 3 working days, which would takes 2-3 months if done manually.

VII. REFERENCES

[1] Chaudhari, P. M., Goyani, J., Arkatkar, S., Joshi, G., and Easa, S. M. (2022) "Design Consistency Evaluation of Two-Lane Rural Highways in Hilly Terrains", Transportation Research Procedia, Elsevier B.V., 62, pp. 75–82.

[2] Eliseev, M., Tomchinskaya, T., Lipenkov, A., and Blinov, A. (2017) "Using 3D Modeling Technologies to Increase Road Safety", Transportation Research Procedia, Elsevier B.V., 20, pp. 171–179.

[3] Gautam, L., Chishi, L. T., Gupta, O., and Kushwaha, P. (2025) "Enhancement of Ring Road in the State of Maharashtra Using Civil 3D Software: A Case Study of Surrounding Solapur City", Innovations in the Development of Sustainable Infrastructure, Springer, Cham, Bangkok, Thailand, pp. 38-51.

[4] Panulinova, E., Baumgartner, M., and Zelenakova, M. (2024) "BIM Models for Road Infrastructure", Information Systems and Technological Advances for Sustainable Development., Springer, Cham, INSTICC, Portugal.,71 pp. 370-375.

[5] Saed, M. M. R. M., and Ewadh, H. A. (2025) "Using Interactive Highway Safety Design Model (IHSDM) to Evaluate the Safety of Signalized Intersections at Kerbala City", Current Trends in Civil Engineering and Engineering Sciences, Springer, Singapore.,2, pp. 453-465.

[6] Said, D., Reyad, F., and Talaat, H. (2023) "Developing Operating Speed Models for Elevated Multilane Urban Arterials Using Artificial Neural Networks", Journal of Engineering and Applied Science, Springer, 70(123), pp. 01-25.

[7] Tanoli, W. A., Seo, J. W., Sharafat, A., and Lee, S. S. (2018) "3D Design Modeling Application in Machine Guidelines System for Earthwork Operations", KSCE Journal of Civil Engineering, Korean Society of Civil Engineers, 22(12), pp. 4779 4790.

[8] IRC : 73 -1980 “Geometric Design Standards for Rural (Non-Urban) Highway”.

[9] IRC : SP: 48-1998 “Hill Road Manual”.

[10] IRC : SP: 20-2002 “Rural Road Manual”.

[11] IRC : SP: 23-1993 “Vertical Curves for Highways”.