Design of Trumpet Interchange Using Civil 3D

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Abstract – *India is approaching towards becoming a developed country, but along with growth in development and research, the growth of population is also observed and is at a faster rate than earlier times. Growth in population means increased number of people, which creates a demand for more transport facilities. To fulfill these needs, one of the sectors that needs more construction is 'Roads'. Roads are considered the easiest and most accessible mode of transport. Being easily accessible and considering the necessity, it is more important to plan and design the road in a safe, effective, economical way to achieve easy movement of traffic on road. Geometric design of highways has an important role in road design, and it is vital in the layout of road alignment. Earlier the designers used manual method which is really a time-consuming method, and cause errors increasing the project cost. AutoCAD Civil 3D, an application widely used by civil engineers and design professionals to plan and design the highway projects. Along with design of highways, the software also has tools and functions to design junctions, interchanges, grade separators etc. This paper focuses on geometric design of such type of interchange, 'Trumpet Interchange' using AutoCAD Civil 3D. The software is capable to design and produce drafts, reducing the time taken to implement changes and assess multiple options faster. Although, number of factors impacts design of interchange, the geometric design with most efficiency, low traffic operation cost, and with safer travel at reasonable cost is final one.*

Key Words: Geometric Design, Civil 3D, Accuracy, Safety

1. INTRODUCTION

In today's age, transportation plays a very vital role. Geometric Design is an important contributing factor in design of highway. In design of highway, safe and efficient travel is priority of the road design. Geometric design is dealing with horizontal and vertical curve, gradient, sight distance, and intersection.

In older days, the drawings were made manually using different tools. A manual geometric design consumes lot of time, more chances of error, leads to increased project cost. Also, the drawing in such scenario has only 2D view and might not be easy to understand.

Civil engineers use Civil 3D, a software application which is used to design and plan projects for road projects, construction of buildings, drainage facilities. Addition to this, it is also used for the construction of ports, dams, canals, embankments. Civil-3D is a very user friendly software used for designing & drafting, which reduces the time taken to apply changes in design and evaluation of multiple scenarios. Any change made in single place of project, dynamically updates an entire project. This helps the designers to work smarter and with high accuracy.

Civil 3D has the ability to create 3D models of any project and can easily adopt small- and large-scale tasks of projects. The software can provide 3D visualization, reducing the time and hence reducing the budget of the project.

2. LITERATURE REVIEW

Harshil S. S. and Shinkar (2016) used civil 3D for designing of bypass road and determined that high accuracy in design and time consumption can be reduced by using Civil 3D.

Sagar Patil, Saniya A., Simran D. (2019) carried out study of Waghbil for geometric characteristics of road such as horizontal alignment, radius, grade, visibility etc.

Sai Raghu (2018) considered different geometric factors like alignment, cross section, profiles etc and explained geometric design of highway and resulted that geometric design must have efficiency for movement of traffic and should be safer.

MHD. Khaja N. and MHD. Aquil (2017) put forward a study about geometric design with the use of MX ROAD and concluded precise design and accuracy for given data using software

Vishal B., (2020) researched the geometric design in terms of improved operation and safety. The important part in the research, which concluded that horizontal curve is always considered logically safe but to travel in a curve safely, the vehicle should be pushed by enough force externally towards the center of curvature. If the force is not enough, the vehicle can drift to the edges of curve and leave the path.

K., Vinoda A. (2018) carried out study of geometric design of rural road using Civil 3D. They concluded that geometric design plays a key role in every road design and it plays major role in the road alignment design. Civil 3D is the most widely used design application by civil design engineers and career professionals to design the projects. As most of the tools used in Civil 3D are dynamic, a change made in one place in a project, automatically reflects in entire project once the project is updated. Civil 3D is also great in compilation of project faster, helpful for designers, hence saving time.

Shivam P., Atul, (2019) carried out design process for a flyover and an intersection using Civil 3D. The research also pointed out that Civil 3D as a resource makes superelevation calculation easy and faster in compilation.

3. STUDY AREA AND LOCATION

The Mumbai Nagpur Expressway known as Hindu Hrudayasamrat Balasaheb Thackeray Samruddhi Mahamarg is a 6-lane wide 701 km long expressway is an access-controlled expressway in Maharashtra, India. It is also expandable to 8 lanes in future as per requirement. It is one of the longest Greenfield Road projects in the country connecting the capitals of the state, Mumbai and Nagpur. The project is being led by Maharashtra State Road Development Corporation (MSRDC) and is designed by top consulting firms of India.

Fig -1: Aurangabad Site Location for Study

The selected interchange is a trumpet interchange which consists of total 4 ramps i.e., 2 directional ramps, 1 semi directional ramp and 1 loop ramp. This interchange is at CH 447+064, also called as Dhule bypass and connects to NH52.

4. DESIGN CONSIDERATIONS

For desired turning movements ramps are provided at interchanges. The connecting ramps are classified as Direct, Semi-direct and Loop ramps based on requirement of movement.

Loop ramp is for right turns accomplished by a left exit and turn to the left through about 270°. A loop ramp may have single turning movement (left or right or double turning movements (left and right) at either or both ends.

Semi-directional ramp for right turns accomplished through a partial duration from the intended path. With semi-directional connection, the driver makes a left turn first, heading away from the intended direction, gradually changing, and then completing the movement by following directly abound and entering the other road. Directional ramp can also be a

a) A connection between the expressway and the crossroad. The driver takes off the expressway on left and merges with the crossroad.

b) For entry to expressway from crossroad, the driver takes off on left and merges with the expressway.

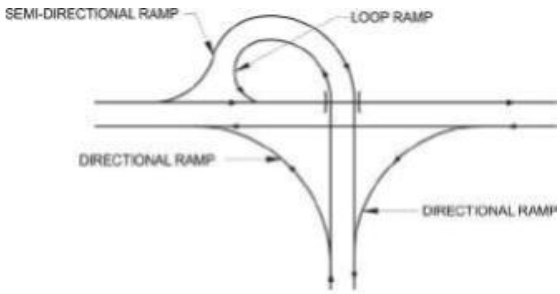

Fig -2: Parts of Trumpet Interchange

Generally, trumpet and T-interchange are the preferred configuration. The advantages are

(a) suitable for three-way junction with no weaving

(b) limited requirement of ROW area,

(c) single point toll booth

(d) provides a relatively high speed (compared to loops) semi-directional turning movement.

5. METHODOLOGY

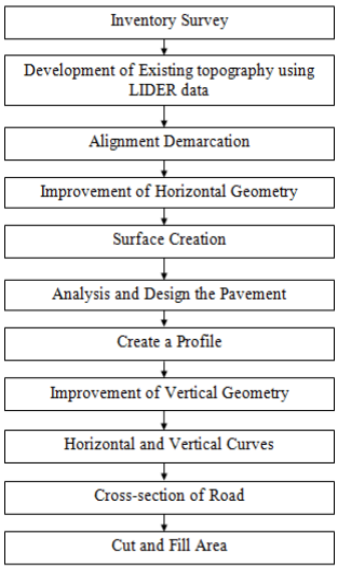

Fig -3: Methodology

5.1 Create Surface

Creating an existing conditions surface and accumulating data on terrain, parcels, utilities, and other factors that could have an impact on the route design are common first steps in road design. To plan the geometry of roadways, one needs to have access to existing ground surface data. The survey company provides the site information. Elevations, easting, and northing are all part of the survey data. To import the points into AutoCAD Civil 3D and construct the existing ground surface, choose the data file containing the survey points.

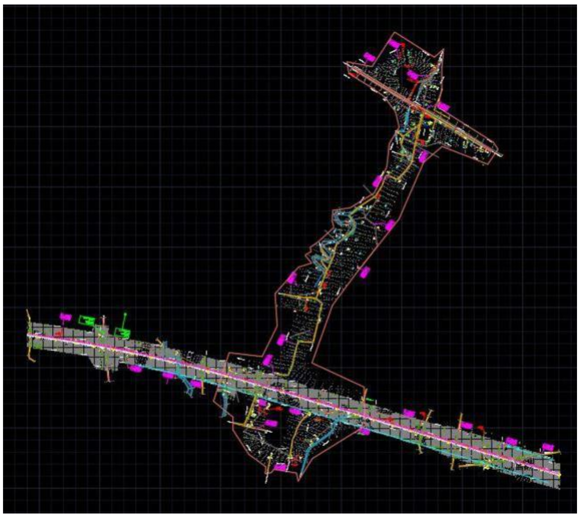

Fig -4: Existing Ground 3D Points

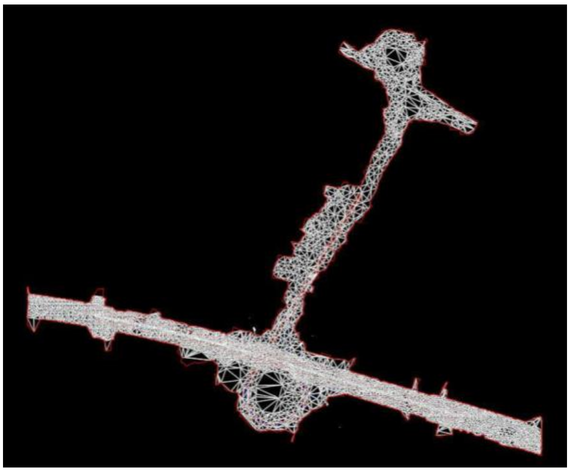

Fig -5: Surface Created from 3D Points (Traingulation)

5.2 Create Alignment

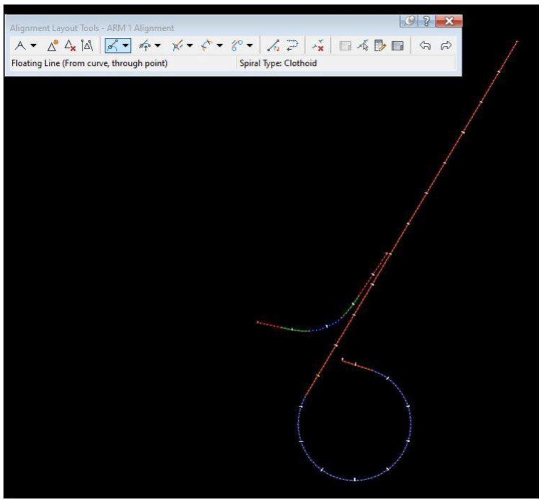

Fig -6: Alignment Created Using Alignment Creation Tool

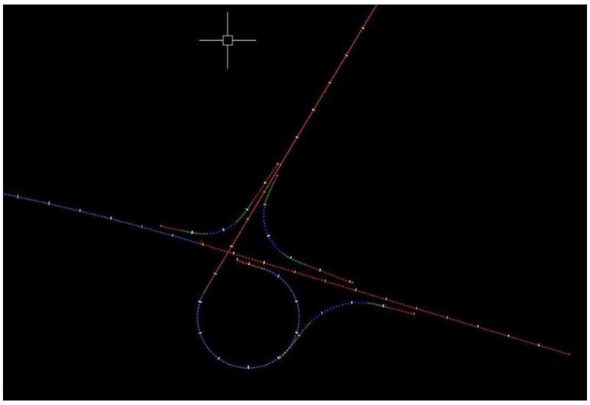

Fig -7: Alignment Created for Loop, Ramp using Alignment Creation Tool

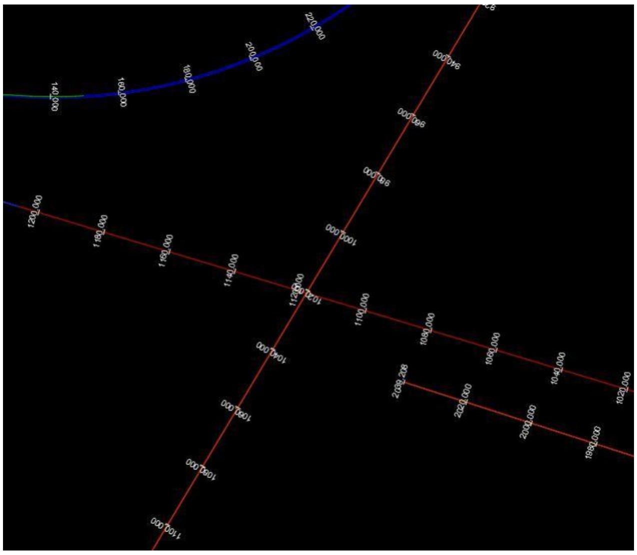

Fig -8: Alignment with Alignment Labels For Chainages

In order to prevent shock to the passenger when a moving vehicle transitions from a straight section to a finite radius curve, a transition curve must be added. The shortest transition period is determined for various speeds and radii.

5.3 Create Surface Profile

Using the alignment designed, next step is to create a surface profile view to plot a vertical alignment which will follow the horizontal alignment simultaneously.

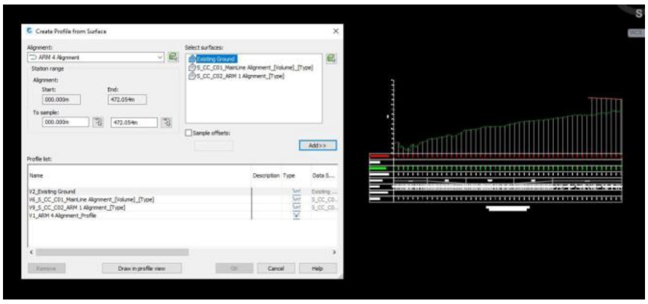

Fig -9: Creating a Surface Profile View using Surface Creation Tool.

5.4 Create Vertical Profile

Using the Surface profile created, we can now draw Vertical Profile for the alignment, which will follow the direction of horizontal alignment as well. This will make sure that grade of the road is proper for good riding experience and also in terms of drainage function as well

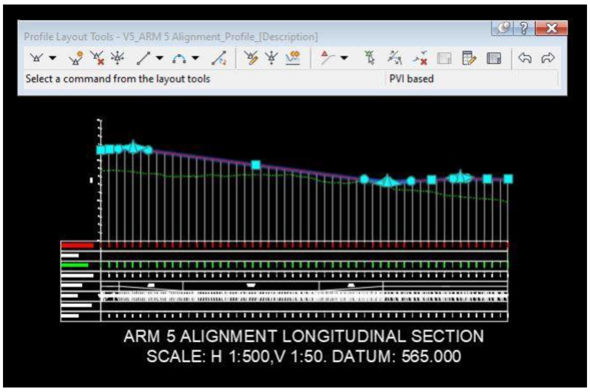

Fig -10: Creating a Vertical Profile using Profile Creation Tool.

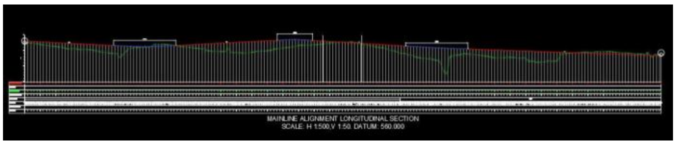

Fig -11: Creating a Vertical Profile using Profile Creation Tool for Mainline.

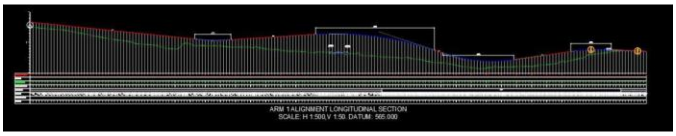

Fig -12: Creating a Vertical Profile using Profile Creation Tool for ARM 1.

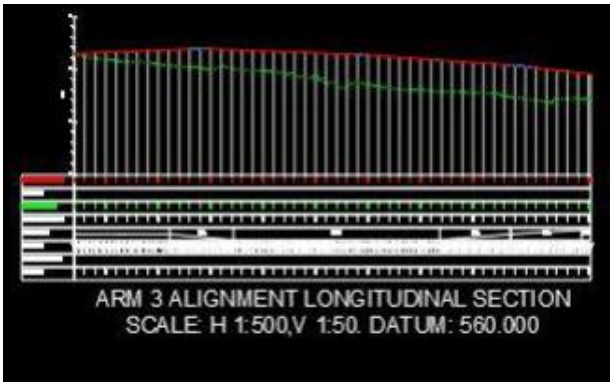

Fig -13: Creating a Vertical Profile using Profile Creation Tool for ARM 3.

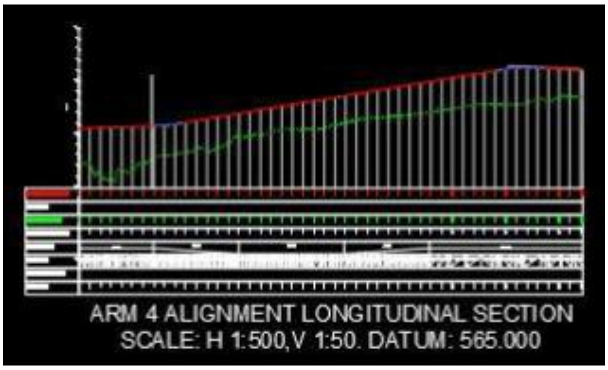

Fig -14: Creating a Vertical Profile using Profile Creation Tool for ARM 4.

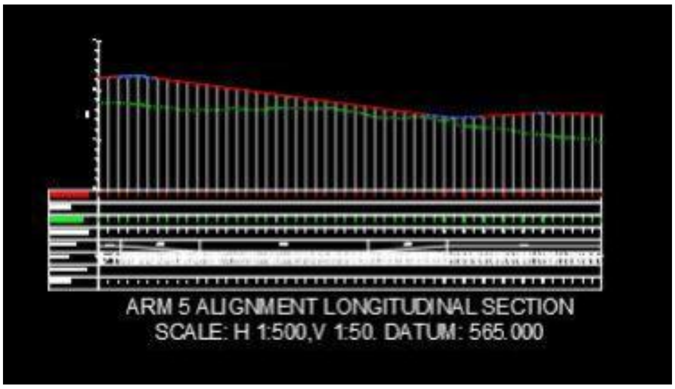

Fig -15: Creating a Vertical Profile using Profile Creation Tool for ARM 5.

5.5 Create Assembly

Purpose of assembly is to define crosssectional platform for the designed alignemnet in Civil 3D Software. 'Subassembly' is a part of assembly. Assembly includes subassemblies such as shoulder, hardstrip, median, verge, carriageway lane for creating typical cross section of road. These subassemblies can be added to either only right or left side of center of cross section or both side as per the requirement.

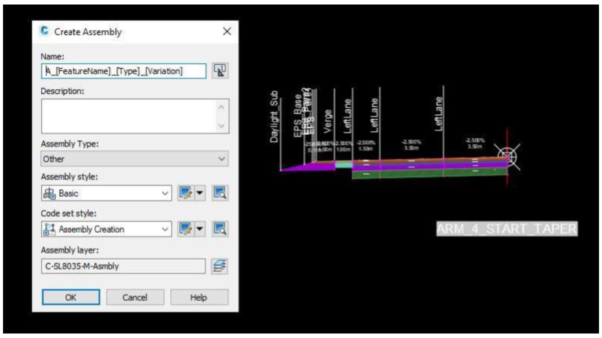

Fig -16: Creating an Assembly using Assembly Creation Tool.

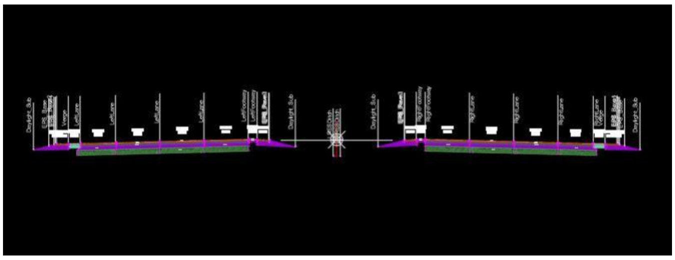

Fig -17: Assembly with multiple Subassemblies.

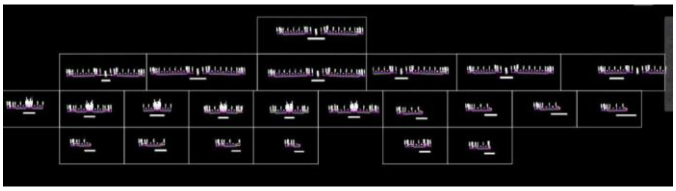

Fig -18: Multiple Assemblies.

5.6 Create Corridor

Using the horizontal alignment, vertical profile and along with assemblies created, we can create a corridor using corridor creation tool.

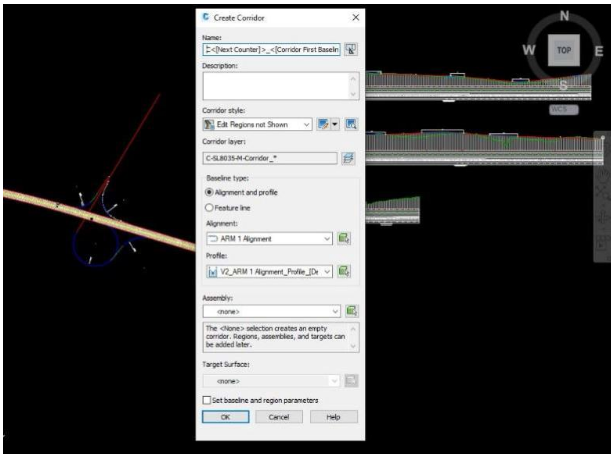

Fig -19: Corridor Creation Tool.

5.7 Superelevation

A transverse slope applied by increasing the pavement's outer edge toward its inner edge to counter the centrifugal force effect and lessen the vehicle potential to flip and skid laterally outward is Superelevation. After determining the horizontal curve radius, superelevation is applied. The "Edit Superelevation" command is used to apply superelevation to the alignment segment.

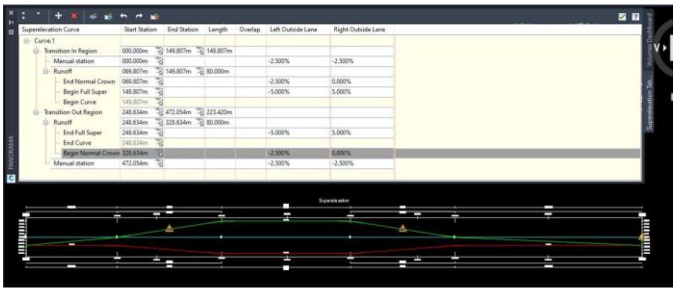

Fig -20: Superelevation Calculation using Superelevation Editor

5.8 Cut and Fill Calculation

Civil 3D has a feature which helps to calculate the required earthwork in a road project. After generating the ground surface and completing grade surface, the feature compares the elevation difference and calculates the volume between two surfaces. Select the surface, and then in Analyze Tab use 'Volume Dashboard'

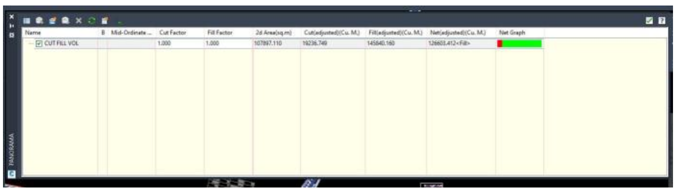

Fig -21: Cut and Fill calculation.

5.9 Final Output

At this stage, all the steps are carried out and we have our final design.

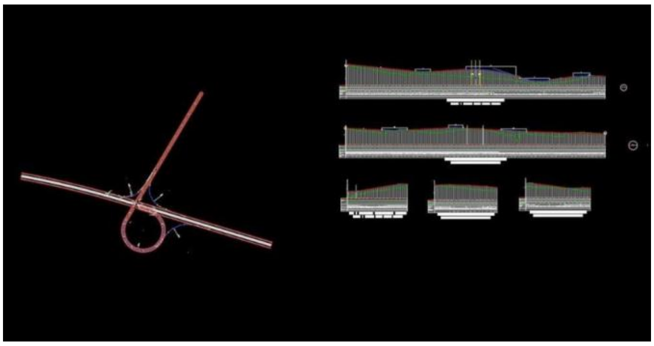

Fig -22: Design Geometry along with Profiles

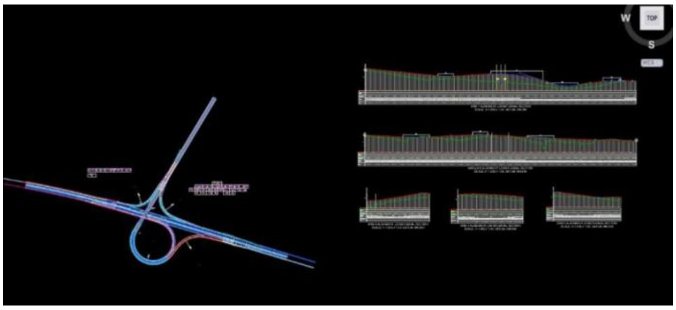

Fig -23: Design Geometry along with Assemblies

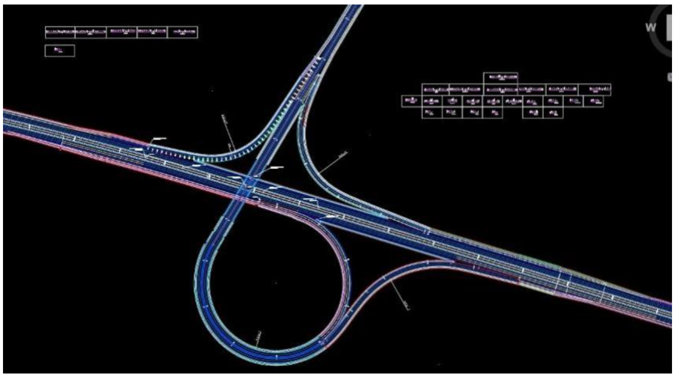

Fig -24: Closer Look of Design Geometry of Trumpet Interchange

Fig -25: View of Design Geometry of Trumpet Interchange

5.10 Perspective View

Now once all the steps are completed, we can view our output in Object Viewer by selecting the corridors and use Object Viewer command to get a perspective view of the design

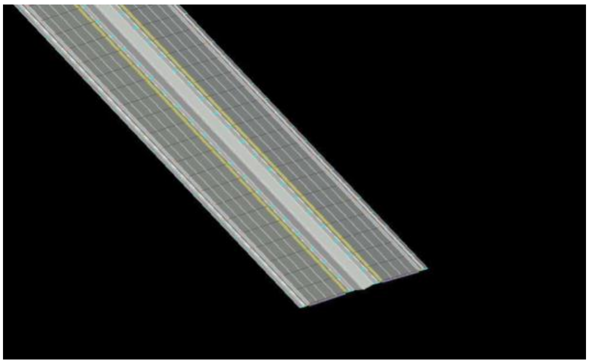

Fig -26: 3D View of Carriageway

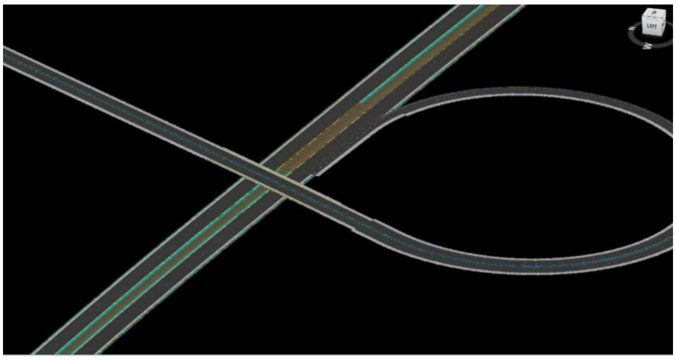

Fig -27: Partial 3D View of Trumpet Interchange

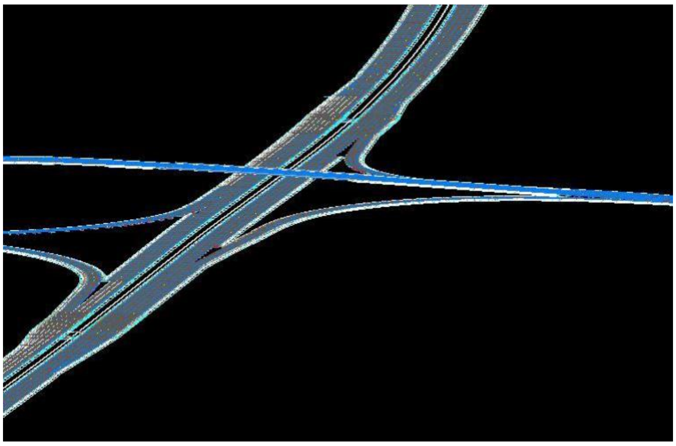

Fig -28: 3D View of Trumpet Interchange

6. Conclusion

AutoCAD Civil 3D assists in completing the design process in a relaxed and comfortable manner while also saving a significant amount of time and effort. The collection of traffic data and the examination of the existing study area assist us in aligning the road in an effective and feasible manner. The spiral transition curve satisfies the requirement for an ideal transition curve. In the project, all curves are plotted in IRC Standard.

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