Computer-Aided Geometric Design of Road and Safety Evaluation Using Vehicle Simulation Model

[1]Pankaj M. Thakare, [2]Vipul S. Bawner
[1]ME Student (Transportation Engineering and Management), [2]Assistant Professor
[1]Department of Civil Engineering.
[1]DRGIT&R, Amravati, Maharashtra

Abstract— **Transportation infrastructure especially concerning to highways facilities includes the geometric components like horizontal alignment, vertical profile and cross section of the road. The design of geometric components has gained importance after the formulation of Indian road plans and expecting the special attention as the country roads are carrying huge traffic along with the tandem and tridem axles. Considering the importance of geometric components of road, it is proposed to design the detailed geometric components of the part of National Highway 548D with utmost accuracy within stipulated timeframe. The project namely "Computer-Aided Geometric Design of Road And Safety Evaluation Using Vehicle Simulation Model" includes the complete geometric design of highway using the computer-aided program, It further involves such tasks as preparation of Digital Terrain Model, creating the road alignment and plotting the alignment profile using bearings or coordinates (easting and northing), stations and elevations of points along the proposed route; calculation of sight distances, radii of horizontal curves, and lengths of vertical curves; design of transitions portions and calculations aimed at finding the optimum alignment while satisfying design standards and constraints. This paper presents a complete geometric design of part of National Highway 548D from Patoda City to Chumbali Phata road, Beed, Maharashtra using AutoCAD Civil 3D software. The one of the partial aim of the project is to demonstrate how roadway geometric design can be performed in a very short time with much ease and precision.**

Index Terms—**Geometric Design, Digital Terrain Model, Civil 3D, AutoTURN**

I. INTRODUCTION

Geometric design for transportation facilities includes the design of geometric cross sections, horizontal alignment, vertical alignment, intersections, and various design details. These basic elements are common to all linear facilities, such as roadways, railways, and airport runways and taxiways. The goals of geometric design are to maximize the comfort, safety, and economy of facilities, while minimizing their environmental impacts. In a typical design project, there is a definite order of tasks, in which the establishment of a tentative horizontal centerline usually precedes establishment of vertical alignment. This is because the elevation of the existing ground along the centerline is an important consideration in establishing the vertical alignment. The process of designing the vertical alignment begins with plotting a profile of the existing terrain and a tentative horizontal centerline must already be established in order to design the same. In design of all above mentioned elements of the geometric design, the software namely AutoCAD Civil 3D is used in plotting the existing details, creating the surface models, formation of digital terrain model, plotting of vertical profile etc. The software analyzed the data as per provided standard and specifications. It gives the optimized design duly checked with the IRC or any other standards. Apart from the above design, the further project work involves the swept path analysis of the designed work that is vehicle simulation for safety evaluation.

II. LITERATURE REVIEW

In 2005, *Mannering et al*. concluded that the design of modern roadways is a sophisticated process that presents the highway engineer with many challenges. A roadway designer often has to consider several design controls and criteria that go beyond the basic application of regulatory standards. Traffic changes, construction costs, real estate prices, vehicle differences, and environmental and ecological considerations are all challenges that civil engineers face. A properly designed roadway takes into consideration mobility and safety issues while addressing economic impacts and environmental constraints.

In 1997, *Ames et al*. presented an Internet-based geometric design software package called Roadway Online Application for Design (ROAD) was developed using the Java programming language with the objective of helping students better understand the roadway planning and design process. ROAD assists students in conducting geometric design on a computer screen with an imported digital contour map as the graphical design reference in the background. Students are able to design the geometry of a roadway more effectively and thereafter can focus more on strategic decisions, transportation planning, and potential environmental and economic impacts. Furthermore, the final geometric design can be visualized in a 3D virtual reality environment using Virtual Reality Model Language (VRML) on a web browser to examine the final roadway design from different perspectives.

III. OBJECTIVES

- Preparation of the Digital Terrain Model (DTM) for the part of National Highway 548D.
- Geometric design of the part of National Highway 548D including intersection using AutoCAD Civil 3D.
- Safety Evaluation of the designed stretch and intersections using AutoTURN (Vehicle Simulation Model).

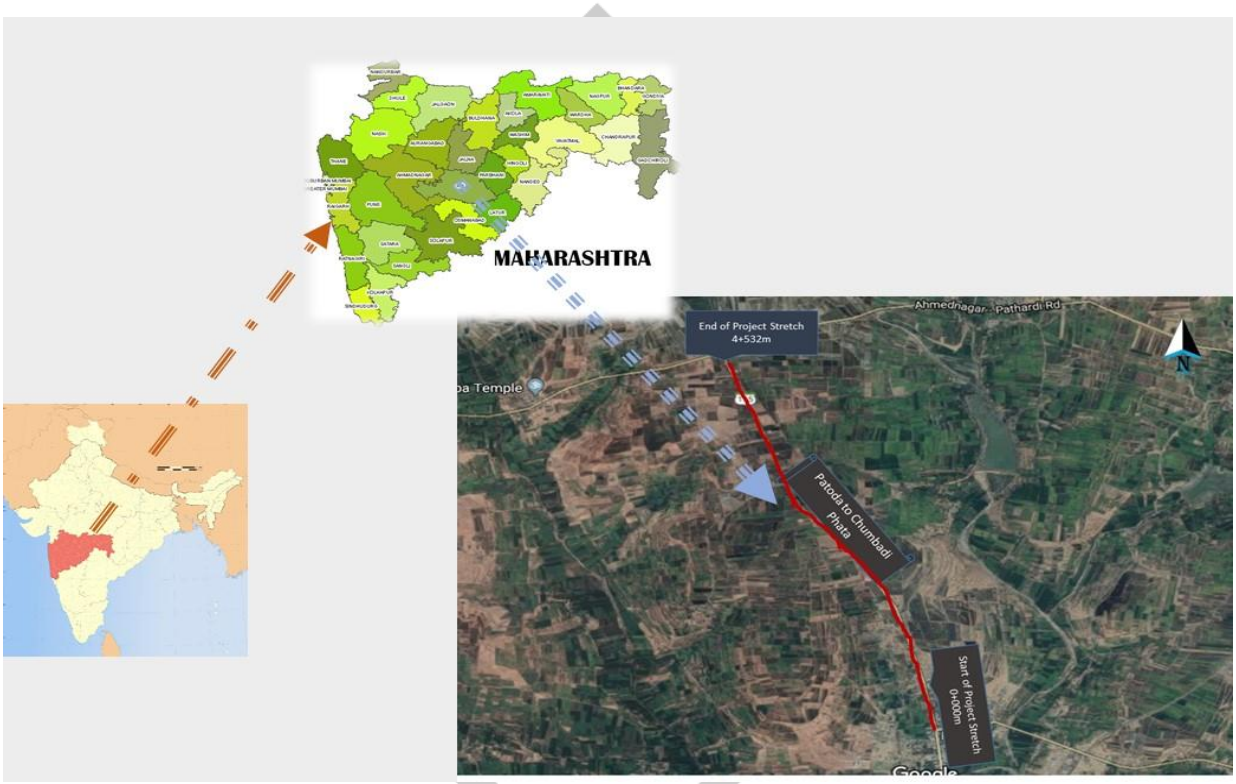
- Validation of designed work by verifying the provided parameters against IRC provisions.

IV. METHODOLOGY

The simplified methodology adopted for the project completion and elaborated as below,

1) Engineering Survey and Investigation- The initial step includes the detailed survey of the project stretch including site assessment, reconnaissance survey, detailed topographical survey, traffic survey etc.
2) Survey Analysis-The step includes the analysis of the survey data including the preparation of basic drawings.
3) Design Base Preparation- The step includes the preparation of digital terrain model by AutoCAD Civil 3D using survey data.
4) Conceptual Design- The step includes the design of various geometric components such as typical cross section, alignment.
5) Detailed Design-The step includes the design of detailed geometric components such as, horizontal curves, vertical curves, super elevations, transition curves, intersection etc.
6) Safety Evaluation-The step includes the safety evaluation of designed intersections using the AutoTURN model.
7) Validation with IRC provision- The step includes the verification of the designed parameters with respect to IRC provisions.

V. SITE ASSESSMENT AND DATA COLLECTION



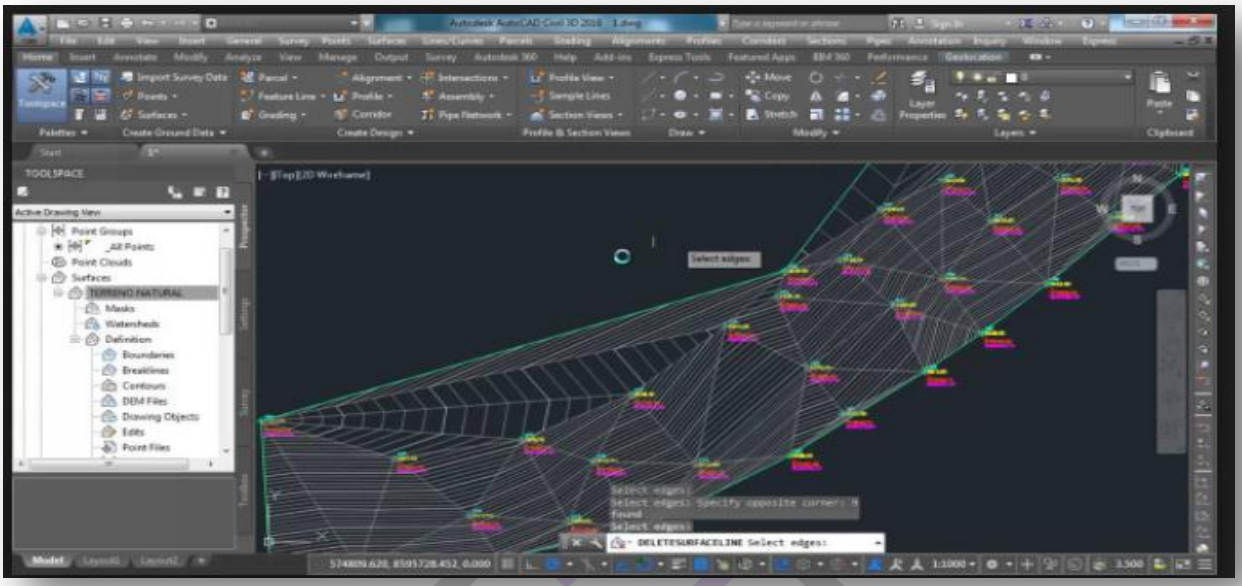
(Project Stretch-Beed District Location)

- Project stretch is located in Beed District of Maharashtra state.
- The length of the project stretch is around 4.5km.
- The project stretch is shown in map with reference of Maharashtra and India Map.
- The project starts from Patoda city at 0+000km chainage (Latitude of 18°48'29.20"N and Longitude of 75°28'54.18"E.) and end at 4+532km chainage (Latitude of 18°50'41.25"N and Longitude of 75°27'50.66"E.).
- The terrain of road through which it passing is plain terrain.
- The traffic survey assess that the magnitude of tandem axle is heavy at the project stretch.
- Survey Data is collected and represented in following format,

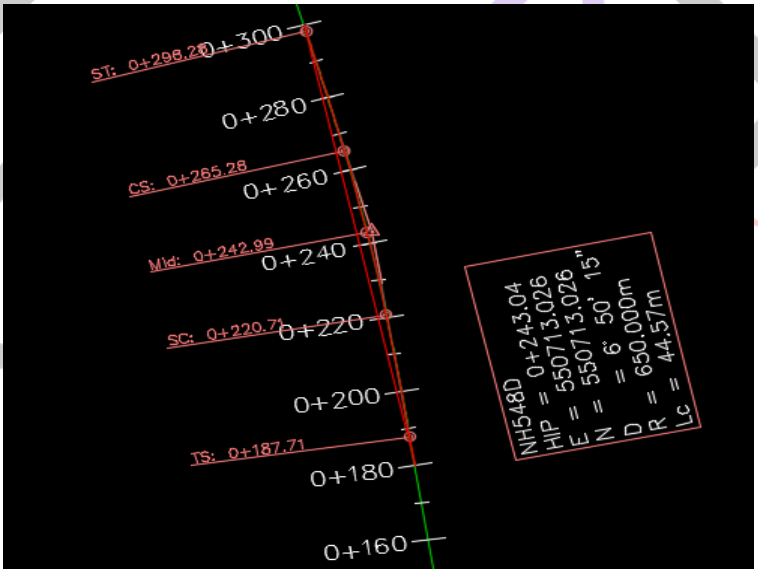
Sr No	Northing	Easting	Level	Code
1				

VI. DESIGN PROCEDURE

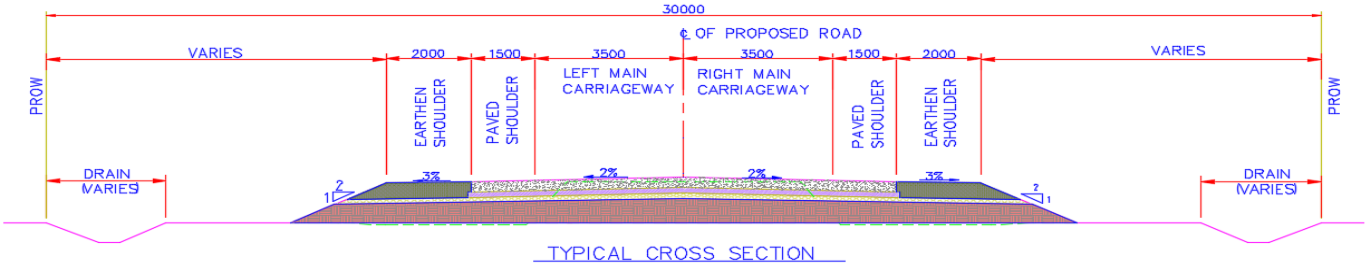
1) Creating Digital Terrain Model- With the reference of three dimensional survey data the Triangulated Irregular Network is created and digital terrain model is prepared, which is as follows,



2) Design of Horizontal Alignment- The horizontal alignment of the project stretch is designed and presented as below,

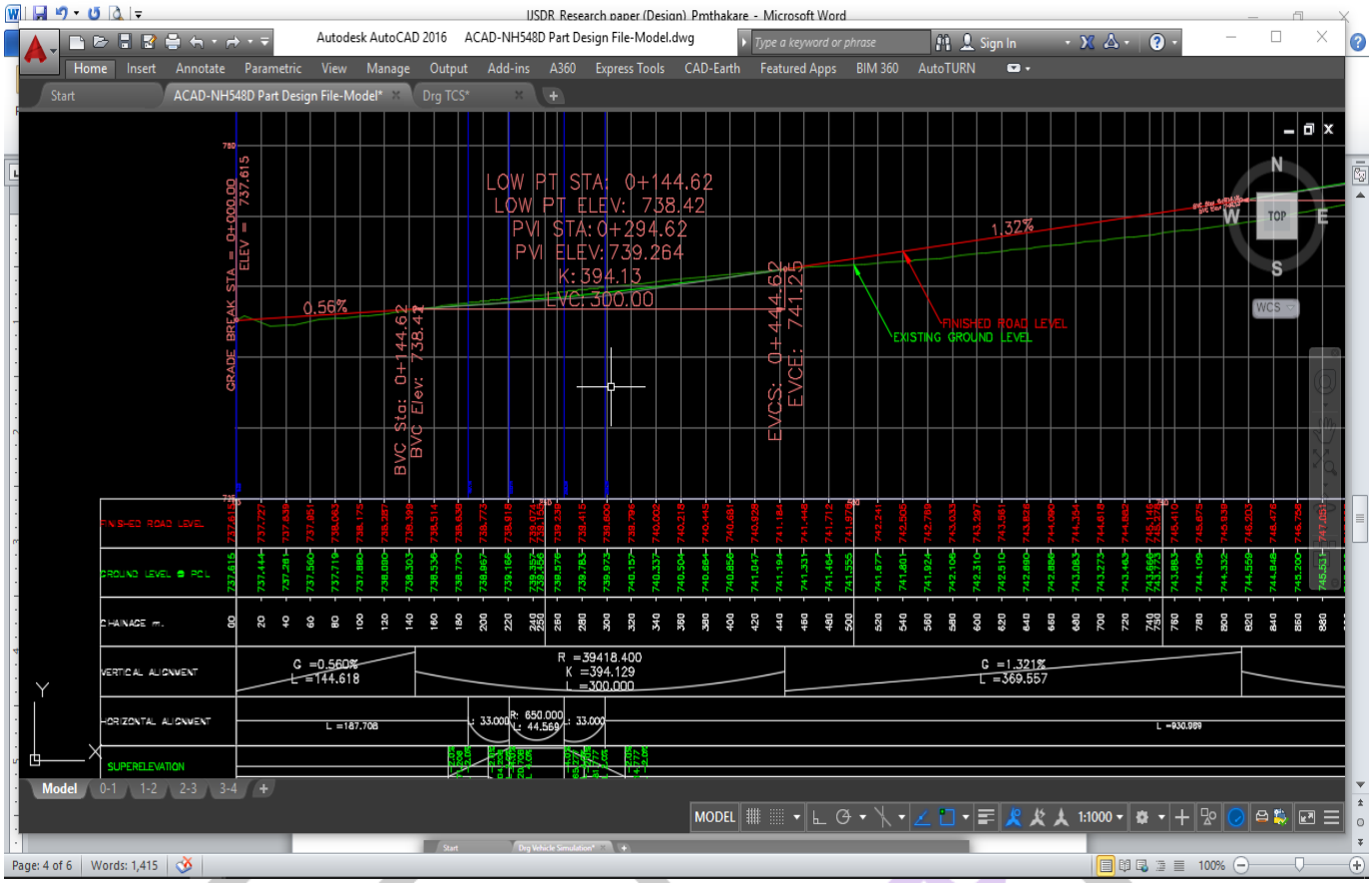


3) Design of Typical cross section- The typical cross section for the road project stretch is designed over the horizontal alignment and presented as below,

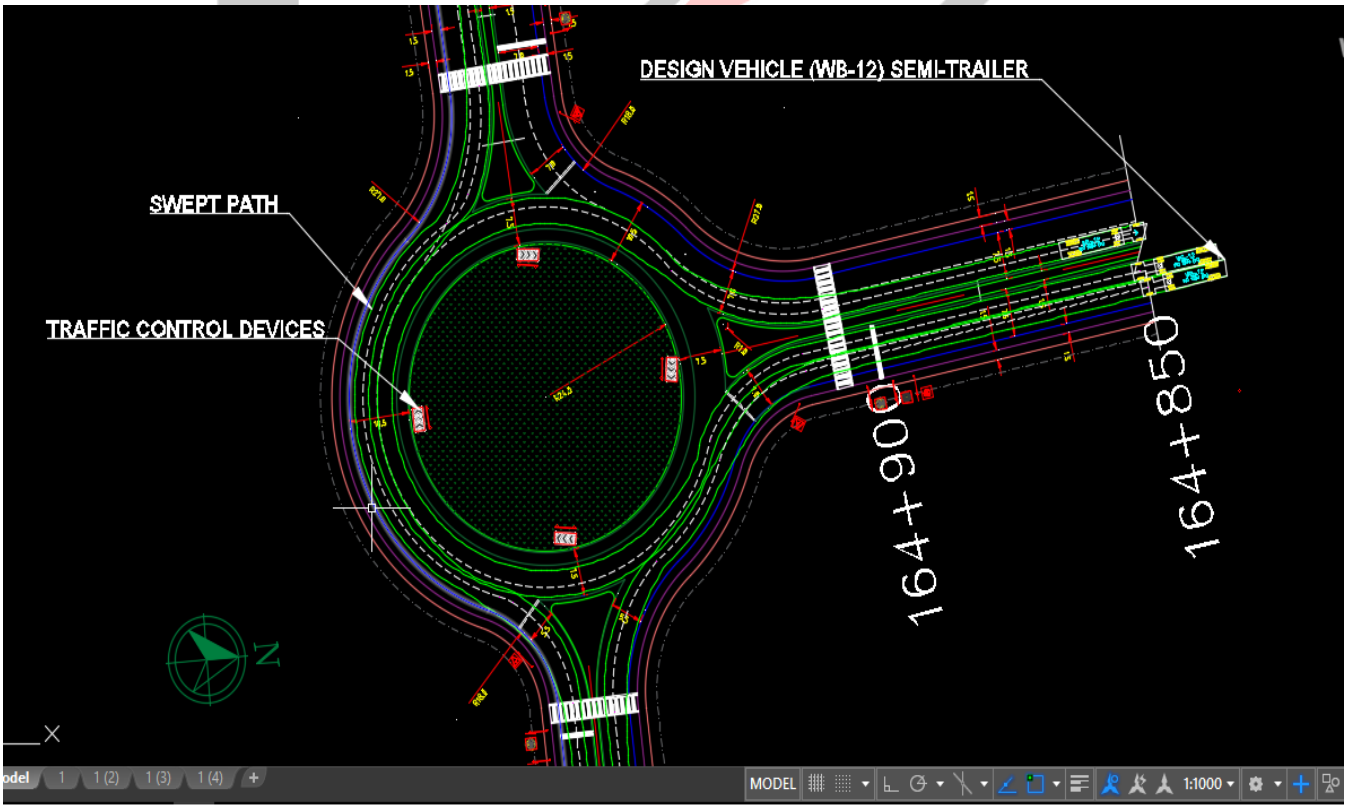


TYPICAL CROSS SECTION
TWO LANE CARRIAGEWAY WITH PAVED SHOULDER–RURAL AREA (RECONSTRUCTION)
TYPE–I

4) Design of Vertical Alignment/Road Profile- The vertical alignment of the road project stretch is designed over the horizontal alignment and presented as below,



5) Design of Intersection and Safety Evaluation- The intersection/junction of the road is designed by considering the existing layout and requirement. The designed intersection is checked with the help of vehicle simulation model (AutoTURN) and presented as below,



6) Validation with IRC provision- proposed key provisions are checked with the IRC norms to validate the design, the same are presented as below,

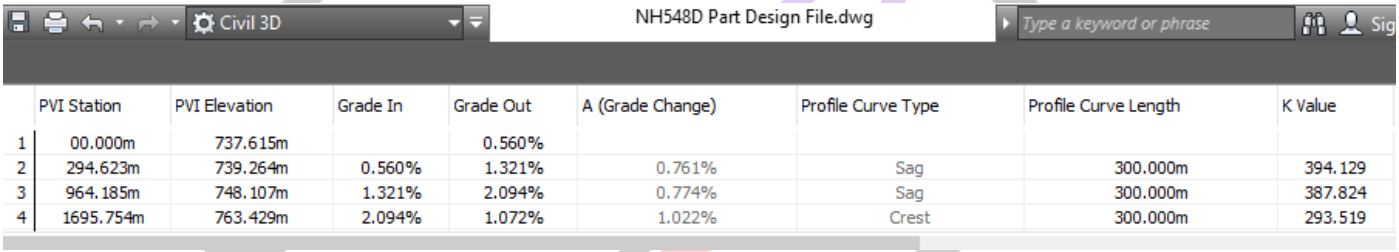
Annexure 11.1 IRC Validation & Compliance				
Sr No	**Particulars**	**IRC Clause**	**Provision**	**Remark**
1	Design Speed	IRC 73:1980, Table 2 (Plain Terrain) Ruling Design Speed 100kmph	Design Speed 100kmph	Followed
2	Cross sectional Elements			
	i) Roadway Width	IRC 73:1980, Table 5 (Plain Terrain) Roadway width 12m	Roadway width 14m	Followed
	ii) Carriage way width	IRC 73:1980, Table 5 (Plain Terrain) Two lane (withour raised kerb)-7.0m Two lane (with raised kerb)-7.5m	Two lane without raised kerb-7.0m Two lane with raised kerb-7.5m	Followed

VII. SOFTWARE RESULT OUTPUT

1) Horizontal Alignment-The horizontal alignment output of the software is elaborated as below,

Parameter C...	Length	Minimum Spiral Length	Radius	Minimum Radius	Design Speed	A	Direction	Start Station	End Station	Delta angle
Two points	187.708m				100 km/h		N8° 49' 40.9...	00.000m	187.708m	
SpiIn-Radi...	**33.000m**	**33.000m**			**100 km/h**	**146.458m**		**187.708m**	**220.708m**	**1.4544 (d)**
SpiIn-Radius...	44.569m		650.000m	492.000m	100 km/h			220.708m	265.277m	3.9287 (d)
SpiIn-Radi...	**33.000m**	**33.000m**			**100 km/h**	**146.458m**		**265.277m**	**298.277m**	**1.4544 (d)**

2) Vertical Alignment-The part of vertical alignment output of the software is elaborated as below,



	PVI Station	PVI Elevation	Grade In	Grade Out	A (Grade Change)	Profile Curve Type	Profile Curve Length	K Value
1	00.000m	737.615m		0.560%				
2	294.623m	739.264m	0.560%	1.321%	0.761%	Sag	300.000m	394.129
3	964.185m	748.107m	1.321%	2.094%	0.774%	Sag	300.000m	387.824
4	1695.754m	763.429m	2.094%	1.072%	1.022%	Crest	300.000m	293.519

3) Intersection-The part of intersection provided parameters are is elaborated as below,

Chainage	Design Parameter	Remark
0+000	Rotary Island Intersection	Ref INT-001
	Design Speed 30kmph	
	Entry Width 7.0m	
	Exit Width 7.0m	
	Entry Radius 18m	
	Exit Radius 27m	
	Weaving width 10.5m	

VIII. RESULT AND CONCLUSION

- The project stretch is designed for the ruling design speed of 100kmph.
- The intersections are designed for the speed of 30kmph by incorporating Rotary Island.
- The better geometric design of high precision within stipulated time is achieved by Civil 3D software.
- The safety assessment of the intersection is completed by carrying out swept path analysis with the help of semi-trailer as design vehicle.
- All the designed components are duly checked with the respective IRC provisions and found in order.

REFERENCES

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