ANALYSIS OF HIGHWAY ALIGNMENT USING OPENROADS SOFTWARE

A THESIS REPORT

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

IN

CIVIL ENGINEERING

With specialization in

CONSTRUCTION MANAGEMENT

Under the supervision of

Dr. Amardeep

Assistant Professor (Senior Grade)

by

Shubham Sharma (192603)

to

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN – 173 234

HIMACHAL PRADESH, INDIA

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May- 2021

STUDENT'S DECLARATION

I hereby declare that the work presented in the Project report entitled **"Analysis of highway alignment using openroads software"** submitted for partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering at the **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Amardeep,** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

Signature of student

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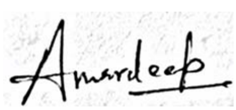
Date: 18 May 2021

CERTIFICATE

This is to certify that the work which is being presented in the project title **"ANALYSIS OF HIGHWAY ALIGNMENT USING OPENROADS SOFTWARE"** in partial fulfillment of the requirements for the award of the degree of Master of Technology submitted in Civil Engineering Department, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Shubham Sharma (192603)** during a period from January 2021 to May 2021 under the supervision of **Dr. Amardeep,** Assistant Professor (Senior Grade), Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of my knowledge.

Date: 18 May 2021



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I earnestly thank our Head of Department 'Prof. (Dr.) Ashok Kumar Gupta' for giving me the shot and also the support for all the time being.

Last however not the minimum, I generously welcome each one of those individuals who have helped me straightforwardly or in a roundabout way in making this project a win. In this unique situation, I might want to thank the various staff individuals, both educating and non-instructing, which have developed their convenient help and facilitated my undertaking.

ABSTRACT

Highway alignment is the layout of the centerline of the road on the ground level. An ideal alignment should be safe, economical, short, and comfortable. This paper presents the improved design standards of the existing road of 4.5 km, which is the part of National Highway Authority of India (NHAI) project using computational design software (OpenRoads). Drivers' speed behavior is investigated on the curves using adhesive tape. Stretch of 500m on the curve is taken in which 400m is the transition before and after the curve and 100m is the curve length and the same was done for the other cures. It reviled that the operating speed is constant along the curves with rapid acceleration and deceleration on the tangents/transitions. Various other parameters i.e. traffic volume, horizontal radius, the cross slope is also calculated manually. This paper shows various alignment models of the road, helping in determining a constant design speed by modifying the alignment to straighter sections and minimizing the speed variations along the stretch. The distance also got reduced after the elimination of curves from the actual alignment. This paper also gives the cost estimation of different alignments that are designed using the software and is compared with the actual structure.

Keywords: OpenRoads, Drivers' Speed Behavior, Horizontal Radius Cost Estimation.

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LIST OF ACRONYMS

AADT	Annual Average Daily Traffic
ASD	Available Sight Distance
CMF	Crash Modification Factor
GIS	Geographic Information System
IRC	Indian Road Congress
SE	Superelevation
SRC	Spiral Roadside Curve
SSD	Stopping Sight Distance

CHAPTER-1
INTRODUCTION

1.1 General

The position of the centreline of the highway on the ground is the highway alignment. The highway alignment in the horizontal plane is horizontal alignment and the alignment in the vertical plane is vertical alignment. Selected highway alignment should be in a way that the overall cost during construction, maintenance, and operation must be minimum and the ideal alignment must be safe, easy, short, economical, and comfortable.

1.2 Factors controlling highway alignment

- Government Acknowledgement: Large investment is required in road construction hence the government should be clear about the requirement and the other features of the road.

- Obligatory points:

    - Negative obligatory points are Ponds, marshy land, religious places, costly structures, densely populated zones that should be excluded from the plan.

    - Positive obligatory points are Existing roads, intermediate towns, existing bridges that should be included in the plan.

- Traffic details: volume of traffic, type of traffic, and the flow pattern of the traffic must be known to determine the number of lanes to be provided.

  Number of lanes = Traffic volume/Traffic capacity

- Geological condition: Stable soil profile should be selected neglecting the soft soil profile.

- Geometric design: Radius of the curve, sight distance and gradient should be safe and fast for the movement of vehicles.

1.3 OpenRoads Designer CONNECT edition

It is a fully functioned, detailed design application for roadway designing. This software allows to:

- Create surveying data through various design elements.
- Different drainage design, cross drainage works, and side drain design.
- Adding or editing subsurface utilities. Adding or editing pavement layers.
- Design various roadway designs like horizontal, vertical, and Superelevation (SE) sections.
- Superstructures like tunnels, bridges, retaining walls are easy to design.
- Calculate and add various cost details and getting the detailed bills.

This software supersedes all capabilities previously delivered through various software like InRoads, GEOPAK, MX Road, and PowerCivil. The saved file has to be opened in its respective software for editing or adding any details to the design. OpenRoads Designer is flexible enough to work with any type of design file extension and supports all features of detailed roadway design including survey data files, geotechnical data, cross drainage systems, subsurface features, terrain files, road design, roadway furniture like various civil cells, and many more. The incorporation of reality meshes, imagery point clouds, and other geo-coordinate data sources helps in the continuous context of real-world conditions throughout the design process and ongoing construction lifecycle.

1.4 Need of Study

The design speed of a roadway design in hilly terrain ranges from 40 to 50 km/h (IRC 52) for highways and 80km/h (IRC SP 99) [1]for expressways. The allowable operating speed is 80-100 km/h for highways and 120-140km/h for expressways in plain terrains. This results in reducing the travel time of the journey which is very helpful in emergencies or in case of national emergencies where a large amount of vehicles has to travel to longer distances in a limited time slot. In plain terrains design speed can be increased easily as the number of straighter sections in the roadway design is more. Similarly, the design speed of the road in hilly areas can be increased by eliminating the curves and introducing straight sections where ever possible. Areas, where curves are to be provided, should be with increased curve radius and proper SE sections. Road widening could also be done along with the curves to increase the available sight distance (ASD)

1.5 Objective of the study

1. To increase the design speed of the expressway up to some extent.

2. To modify the alignment or the other features where ever it is required.

3. To compare the cost estimation of modified alignment with the actual cost of the project.

CHAPTER-2

LITERATURE REVIEW

2.1 General

Several studies have been carried out by researchers using various software, for the highway alignment. Softwares like MX Road, Geopak, HEADS, MicroStation, InRoads are widely used for the design of highway alignment. This software has its benefits and drawbacks too. Presently OpenRoads software is dominating the other software as it is the more refined version of the previously used software.

2.2 Literature Review

Francesca Maier et.al. (2017) [2] conducted a case study on various projects that are under state transportation agencies and have a vast need for renewal. 3D design data was used for risk management during the planning so that during the construction period everyone would get aware of the risk at the construction site. Verification and 3D data-based pavement quantity measurements improve safety and efficiency for quality surveyors which result in more accurate, transparent, repeatable measurements and yield a more complete record of construction.

Qing Chong You et.al. (2016) [3] conducted a study on innovative roadside curves for lateral clearance. It was told that any obstruction on the horizontal curve should be cleared to satisfy sight distance requirements. Various cases were studied and spiral roadside curves (SRC) were designed and analyzed. It was known that introducing spiral curves with circular curves provides the available sight distance (ASD) greater than stopping sight distance (SSD).

Juneyoung Park et.al. (2017) [4] conducted a study in which various crash mod factors (CMF) were developed at non-curved and curved roadway sections using cross-sectional methods. It was observed that increasing lane and shoulder width will be effective in reducing the crash frequency in general. It was also found that the CMFs for increasing lane and shoulder widths are decreasing as the annual average daily traffic (AADT) level increases.

Min-Wook Kang et.al. (2013) [5] conducted a study in which conceptual methods for evaluating fuel efficiency and sight distance deficiencies. An SD model automatically calculates available sight distance and stopping sight distance and also evaluates SD deficiencies of alternative alignments.

Richard Coakley et.al. (2016) [6] studied the relationship between design features and performance. It was concluded that the design process should cover all the alternatives for the geometric design process. Roadway design should therefore recognize the full design, construction, operations, and maintenance implications of all substantive geometric design decisions.

Srikanth B. and Raveesh J. (2019) [7] conducted a study in which road geometric design is imported to MXroad software and is related to the design standard as per respective code. Geometric features like horizontal radius, SE, k-value, and visibility are analyzed. It is known that the horizontal radius was less at some curves, besides this the whole alignment is satisfactory.

P. Nimitha et.al. (2017) [8] conducted a study to establish the alignment of a highway for the widening of the road from two-lane to four-lane with the evaluation of soil strength. Different data was collected and a model was prepared on MX Road software. The earthwork was calculated for the new alignment.

S. Marisamynathn et. al. (2016) [9] conducted a study of a signalized intersection. Field data was collected at the selected intersection and traffic volume was determined. The volume/capacity (V/C) ratio was calculated as per IRC – 106 (1990) [10] and was projected for the next 10 years. The projected volume was exceeding than maximum capacity and hence a flyover was designed using MX road software.

Ali Ashraf et.al. (2018) [11] conducted a study to analyze the road alignment for a stretch of 1.51 km. Road design was imported to the software by GIS (Google earth). It is observed that there is some deviation in the road design and the actual alignment. It is suggested to increase SE up to 7% and widening up to 1.43m on curves.

Badake Sanju Kumar and Malothu Narasimha (2017) [12] conducted a study to design a flexible pavement (IRC 37) and have a cost estimation of the project. MX Road software was used. The design speed of the highway is decided to be 100km/h.

Sachin Dass et.al. (2010) [13] conducted a study to compare MX road and HEADS software for better and precise performance. MX Road software results to be more flexible than HEADS due to the friendly environment with AutoCAD and MicroStation. The surface checker can also be used in MX Road to identify any incomplete or incorrect data.

Aditya Kalra et.al. (2018) [14] conducted a study to widening the existing road stretch of 3 km. and getting the estimation of the project using MX Road software. The data of the existing road was collected and was plotted to software. The software successfully widened the road patch for the two-way lane with an estimation of about 60 lacks.

2.3 Summary

The software used in the above papers gave satisfactory results for every design of the highway alignment.[15][16] They help in analyzing various alignments in very little time hence they are time efficient. Cost estimations are also known for different alignments. These softwares are to be used efficiently so that any design approach should not be left behind and the most efficient alignment is chosen.[17] Softwares reduce the workload of a person in preparing design data files. A driver should feel comfortable while on road. The expectations of a driver should be fulfilled.[18] The software also helps in determining the speed behavior of a driver eliminating the requirement of various mechanical speed behavior modals. The values can be known on the software and the alignment can be designed according to the speed behavior. Various features can be added to the road profile to maintain the constant speed behavior of the driver. [19] Superelevations can be tested easily for varying values, in software. [20]

CHAPTER-3
METHODOLOGY

3.1 General

This chapter gives details about the software used, various formulas used by software to design the road, collection of the terrain and survey data, detailed experimental setup, and different methods used to achieve the objectives of this project. Ner-chowk bypass of length 4.5 km is taken for the analysis. The actual design is taken from the company (IL&FS). Detailed cost estimation is also taken for the existing alignment. This will be useful for the comparison between the cost of existing and modified alignment. The total cost estimation also helps in determining the precision of the software.

3.2 Software description

OpenRoads Designer CONNECT Edition is the latest software of Bentley giving a wide range of features to its uses and is an update to Bentley's industry. Leading from various civil engineering designing brands which include InRoads, GEOPAK, MX Road, HEADS, and PowerCivil. Openroads is an inspiring, design application that is built to address the demands of the present blooming infrastructure industry. Combining various traditional engineering work for plan, profile, and cross-sections, all along with 3D modeling, OpenRoads enables the model-centric creation of all design perspectives. OpenRoads supports all aspects of a detailed roadway design including survey data, importing or creating geotechnical data, sub-drainage design/ cross drainage works, subsurface utilities, corridor modeling, analysis of road structure covering various aspects, cost and quantification of materials, and much more. It is a comprehensive, multi-discipline 3D modeling application that advances the delivery of roadway projects from conceptual design through construction. OpenRoads have the latest technology and wide range of tools one needs, to efficiently design any roadway model, and produce project deliverables in a dynamic, interactive, and parametrically enabled environment. The software also allows the creation of various exporting file extensions that helps in sharing the design to various other platforms.

The user interface is very similar to MS Office making the software much easy to operate. The tools and other ribbons are very similar to other road design software which makes it more user-friendly. This software saves a lot of time as manual updating of design contents is not necessary.

Design contents can be imported from any platform like GIS (google earth), AutoCAD drawings, TIN files for terrain data import, and many more formats. There is also an inbuilt library for various design parameters of different countries which makes things more simple and easy to analyze from country to country. Where ever the design parameters are not up to the mark error will be shown and hence the changes can be made accordingly.

3.3 Technical terms according to IRC codes

The software has an Indian Standards library which has to be installed in the software. After this, each design aspect is designed as per the respective IRC codes.

1. Horizontal alignment: This is defined as the tangents and the curves horizontally. It includes the transition length, curve radius, and curve angles. All these aspects are calculated by the software automatically concerning Indian standards. Figure 3.1 shows the design aspect of a curve in the software according to IRC 52 [21] and IRC 38[22]

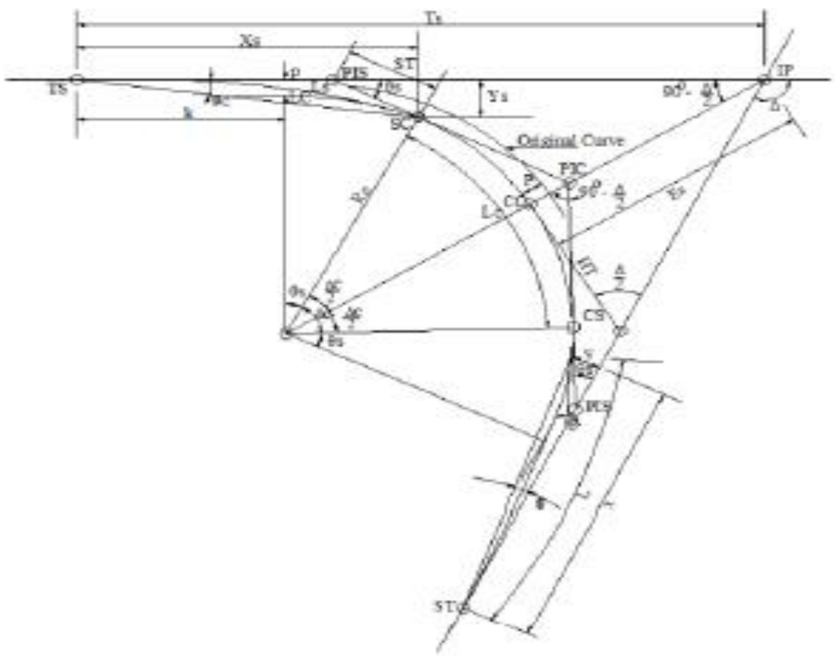


Fig. 3.1 Horizontal Alignment as per IRC Guidelines

2. Vertical Alignment: It is the section of road in the longitudinal direction for a change of gradient at the ground level. It includes slopes, gradients, and vertical curve sections. The rate of rising concerning horizontal alignment, along the length of the road is called gradient and is measured in

percentage or ratio in degrees. All these aspects are calculated by the software automatically concerning Indian standards. Figure 3.2 shows the design aspect of an elevation according to IRC 52. [21] and IRC SP 23 [23]

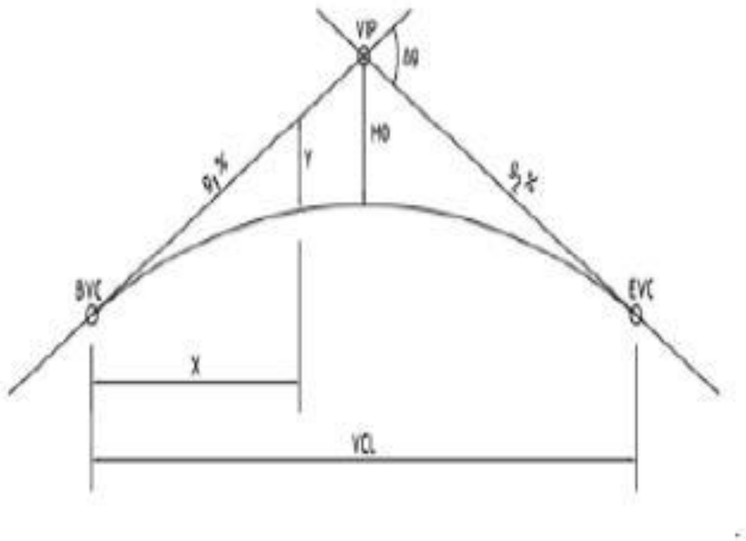


Fig. 3.2 Vertical alignment as per IRC Guidelines

3. Superelevation (SE): It is the transverse slope provided to counteract the effect of centrifugal force and reduce the tendency of the vehicle to overturn and to skid laterally outwards by raising the pavement outer edge concerning the inner edge. It is calculated as-

$e + f = V^2/127R$ ……………. Eqn. 1

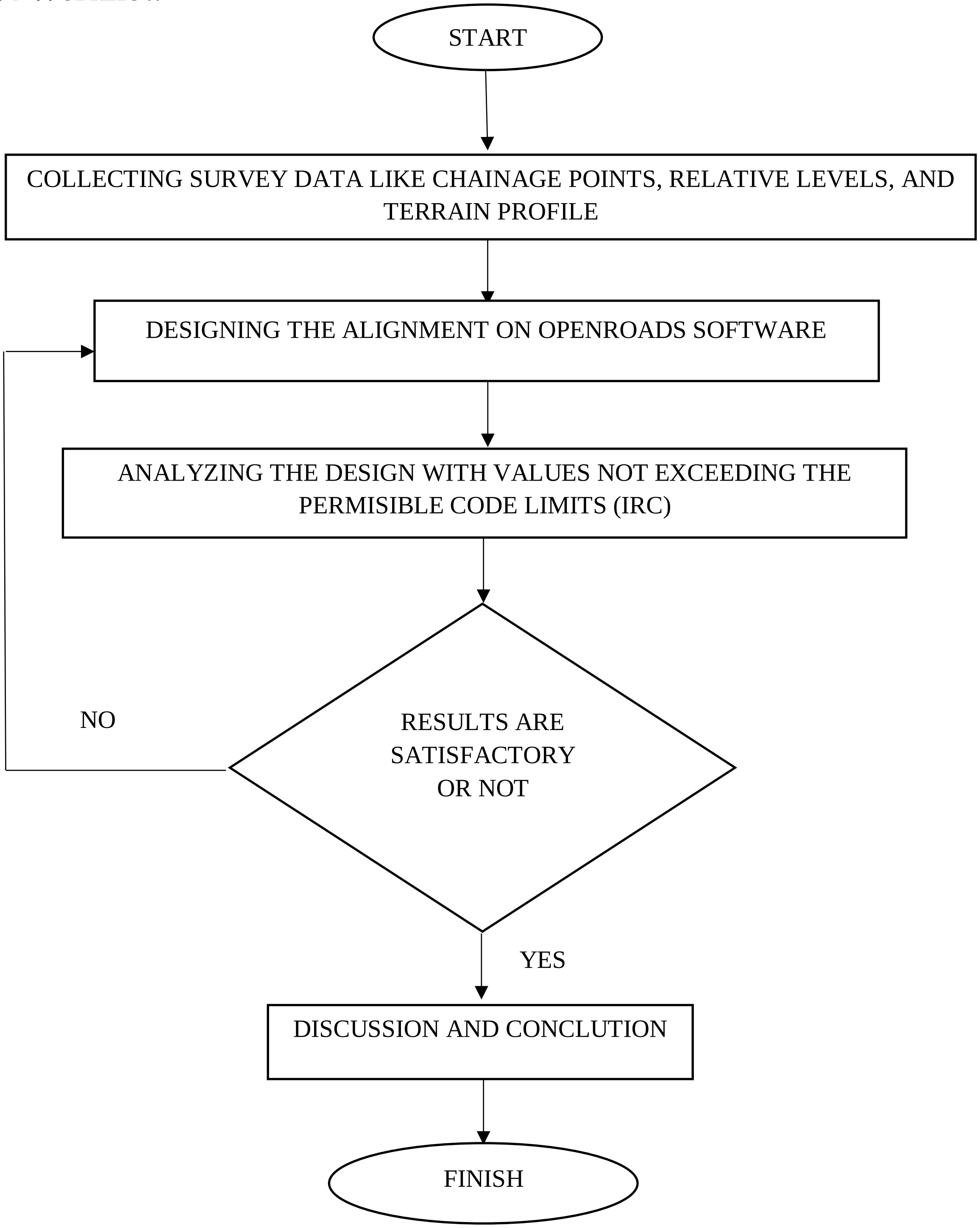
e = rate of SE in %

f = lateral friction factor (0.15)

v = velocity of vehicle in km/h

R = radius of the circular curve in meters.

3.4 Workflow


START
COLLECTING SURVEY DATA LIKE CHAINAGE POINTS, RELATIVE LEVELS, AND TERRAIN PROFILE
DESIGNING THE ALIGNMENT ON OPENROADS SOFTWARE
ANALYZING THE DESIGN WITH VALUES NOT EXCEEDING THE PERMISIBLE CODE LIMITS (IRC)
RESULTS ARE SATISFACTORY OR NOT
NO
YES
DISCUSSION AND CONCLUTION
FINISH

3.5 Collection of survey data

Chainage points were known according to the kiratpur-ner chowk expressway project. A bypass section of this project is taken for the study. The ner-chowk bypass is taken for the study which has chainage points from 178+018 to 182+428. The GIS data is extracted from Google Earth. In figure 3.3 the road marked with a red line is the existing bypass taken for the study. The green lone is the older road that passes through the ner-chowk city which had to be eliminated and this bypass was proposed. The chainage points are mentioned in the figure in actual order. The whole section is selected within the yellow box and is saved in .kml file format. It is done to extract the topographical data.

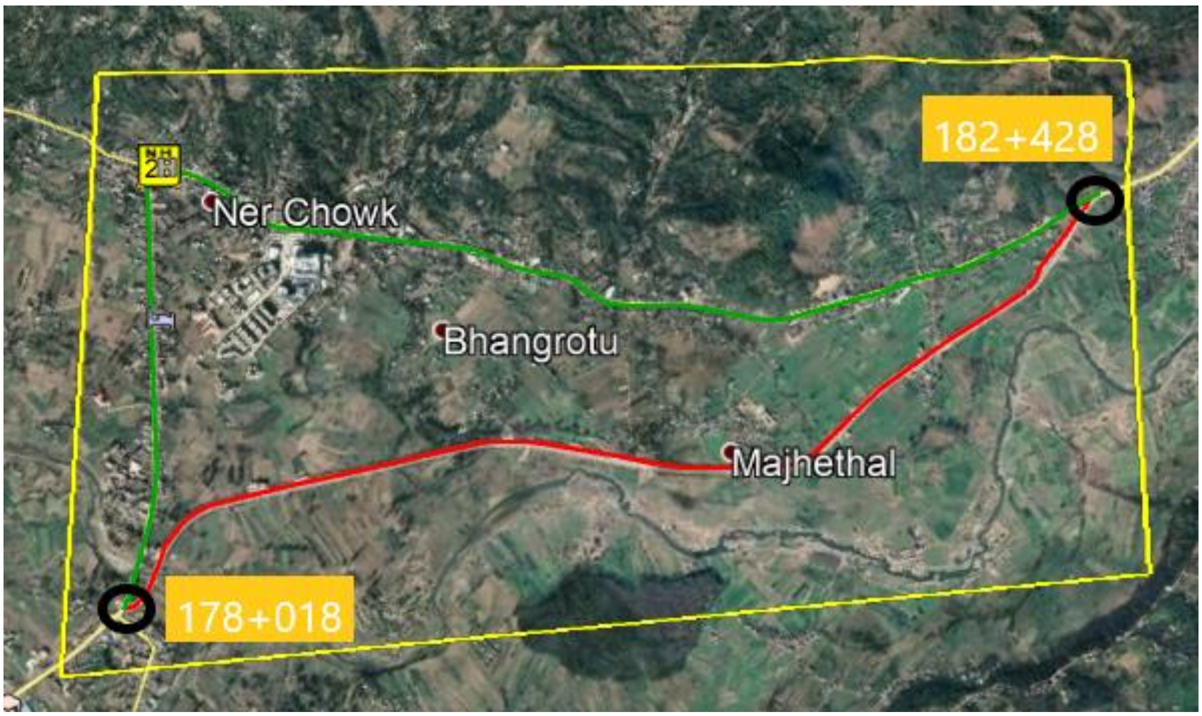


Fig 3.3 Existing road alignment with chainage points   Source - Google Earth

3.6 Northing and Easting values at different chainage points

All the coordinates of the road are known and extracted from google earth. Longitudinal (northing) and latitudinal (easting) coordinates are taken at every +10m chainage points. These are taken to set the actual coordinates of the road in the software which is used to extract the actual topography of the alignment. All these points help get the relative height of the various chainage points. These points are imported in MS-Excel from google earth. We can create a terrain file from these points also in OpenRoads but only the road terrain will be imported and the area terrain file would not be obtained. Hence we are using Global Mapper software to get the terrain file of the whole area so that modified alignments can be created at ease.

Table 3.1 Northing and Easting points at different chainage points

Chainage points	Northing	Easting
178+018	76.92605	31.59741
178+218	76.92546	31.59744
178+418	76.92546	31.59744
178+418	76.92489	31.59845
178+618	76.92475	31.59973
178+718	76.92475	31.59973
178+800	76.92451	31.60075
178+900	76.92451	31.60075
179+100	76.92528	31.60221
179+300	76.92562	31.60293
179+500	76.92729	31.60516
179+700	76.92783	31.60631
179+900	76.92938	31.60837
180+115	76.93017	31.60932
180+317	76.93095	31.60958
180+524	76.93287	31.61124

180+700	76.93386	31.61192
180+900	76.93561	31.61347
181+120	76.93761	31.61512
181+320	76.93761	31.61512
181+540	76.93885	31.61724
181+700	76.93885	31.61724
181+950	76.93898	31.61902
182+009	76.939	31.62
182+095	76.93956	31.62106
182+170	76.93983	31.62211
182+280	76.94074	31.6244
182+320	76.94091	31.62588
182+428	76.94124	31.62742

3.7 Field investigations

In road inventory, the length of the road is measured along with the land used. The terrain was determined. The width of the carriageway and shoulder was measured and the present pavement condition is checked. The various measurements are given in table 2.

Traffic volume survey data was also collected and is shown in table 3.3. The number of vehicles crossing a section of road per unit time at any particular time. (Usually, peak hours are considered)

Total number of vehicles in both directions at peak hour (n)= 369+25 = 794

50% of the n is taken = 397

Average daily traffic = 3,970 vehicles/day

Table 3.2 Road Inventory of existing road

Geometric features	Existing Road
Length	4,587m
Width	22.0 m
Number of lanes	4
Traffic moment	2-way
Divided / Undivided	Divided (4.5m divider width)
Shoulder type	Earthen shoulder 2m wide
Pavement Drainage Condition	Moderate
Road Side Drainage	Poor
Land Use	Commercial and Residential

Table 3.3 Traffic volume data

Morning Peak Hour							
Time	Car	Mini bus	Bus	2-axle truck	JCB	Tractor	Total
8:00-10:00	280	15	13	40	4	17	369
Evening Peak Hour							
5:00-7:00	320	22	15	55	2	11	425

3.8 Creating terrain modal in Global mapper software

1. After saving the place as .kml file format from google earth, the file is opened in global mapper software to extract all elevation data of the area.
2. The datum zone is also known for the area from google earth. After importing the file in global mapper the actual coordinates are saved for the file to which elevations are to be added.
3. For this project, the datum zone is 43R. From the coordinate library in global mapper 43R zone is selected.

4. Click on connect to online data and STRM worldwide elevations, topo map, world imagery, and then generate contours are imported.
5. The generated file is exported in .dem and .dgn file extension .dem file extension is for terrain modal and .dwg file is for the reference file that is to be imported in OpenRoads software.

In figure 3.4 the imported contour lines and different elevation points of the area are shown that are generated as in global mapper software.

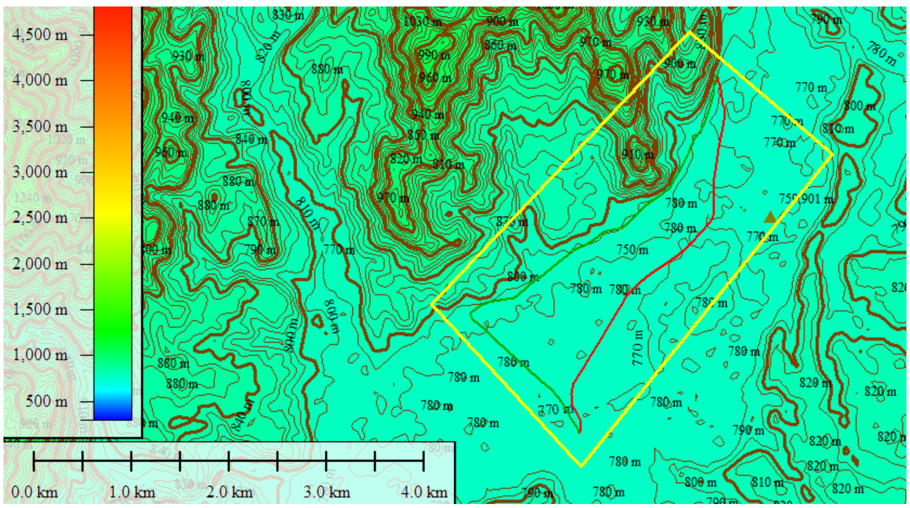


Fig. 3.4 Terrain file generated in Global Mapper software

3.9 Designing the alignment in OpenRoads software

1. Select the workspace as Indian Standards and create a file with ‘seed 2D’file. This file is only to import the terrain data in OpenRoads and make the reference file. Once the terrain is imported this file can be closed and a new file is created with ‘seed 3D’ as the designing part would be done in a 3D file only.
2. Open Settings in the File menu and open ‘design file settings’ and set the units to km for Indian standards which designing work has to be done. Open the ‘Reference’ tool and attach the terrain file that was created in 2D format, and merge it to the master modal. Click on the ‘Fit View’ button and a green outline will appear on the working window. This is the terrain modal. The contours and other features of the terrain file can be enabled by hovering over the boundary line and open the properties from the dialogue box that appears. By simply turning on or off the contour options we can enable the contours of the file.

3. Open the reference tool and attach the .dgn file created earlier from the global mapper. Check the option to the coincident world and click on open. From the ‘Level Display Manager’, the contour line can be turned off and the road alignment lines from the .dgn file will appear which is the existing alignment. The feature of the line is not defined hence it can’t be used for further design.
4. In general, tools open the standard ribbon and enable the ‘Design standard toolbar’ and feature definition toolbar. Activate the feature definition as ‘India centerline alignment’. Select the ‘Line’ command from the horizontal ribbon and create the straight sections of the existing alignment. Once all the straight sections are created, use the arc command from the same horizontal ribbon and activate the feature as done earlier. Select the 2 elements to connect with arcs. Select the back offset for both elements and the arc will be created with a varying radius. The existing alignment’s curve radius is known and the radius is entered for the arc creation. Similarly, other curves are designed and matched with the existing alignment as shown in figure 3.5. Using the ‘Complex Geometry’ tool create the whole alignment as a single element. Using the ‘Design Standard Toolbar’ set the design speed of the centerline of the alignment.

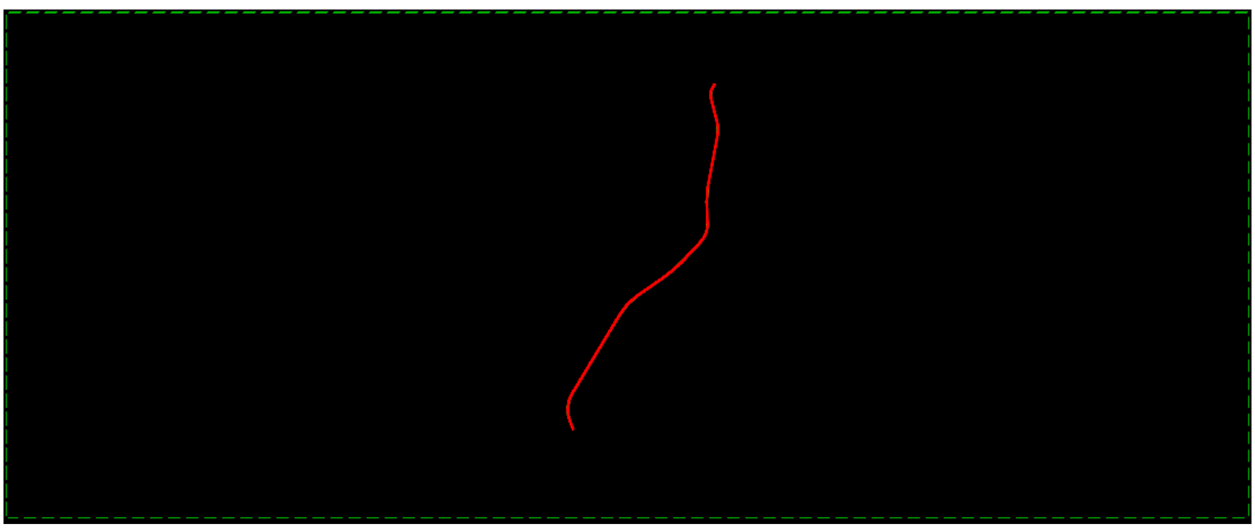


Fig. 3.5 Centerline of the alignment E

5. Once the centerline is created, the vertical profile has to be drawn to create SE sections, pavement layering, or different lanes of the road.

6. To create vertical alignment set the terrain profile as an active profile. Using the element selection tool select the centerline and hover over the selection. A ribbon with various tools will open. From those tools select the second option i.e., 'Open Profile Model'. Clicking on it the option will ask for the selection of view in which the vertical profile is to be created. Open 'view 2' and right-click in the view window. The existing ground profile will appear with all the station curves.
7. In the geometry toolbox under the vertical section, 'line and curve' commands are present the same as in the horizontal tab. Select the line tool and activate the feature definition as 'geom baseline' and enter the start point or take the mouse pointer to the starting point and left-click. The line will start from the point of click and design the vertical profile as the existing profile of the alignment. All slope details are being shown as the mouse pointer moves. Enter the endpoint and the vertical profile will be created as shown in figure 3.6. In the figure, the green dotted line is the existing/ actual ground profile and the red line is the vertical alignment that is created.

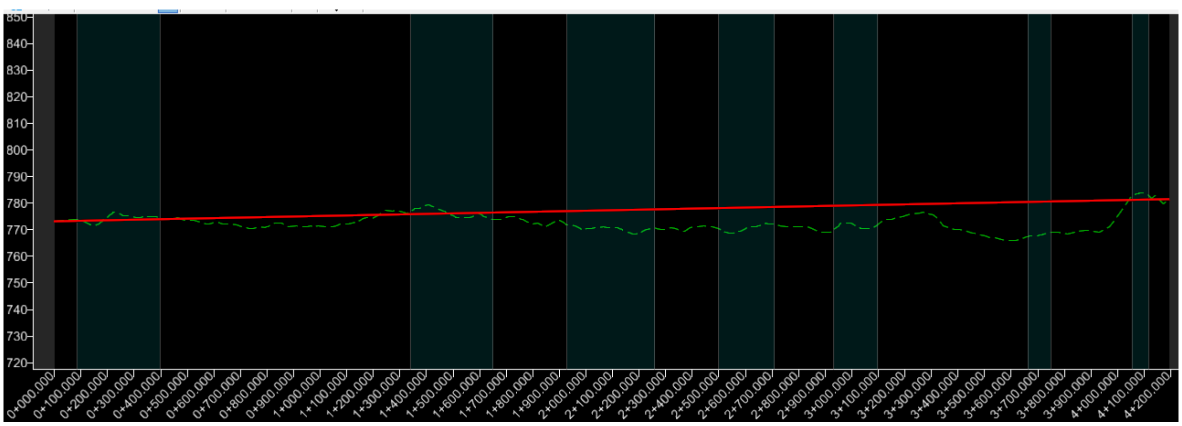


Fig. 3.6 Vertical alignment of E

8. Open the corridor tab and select 'Create SE sections' under the SE ribbon. A dialogue box will appear, add the desired name to the SE section, and locate the centerline. After locating the centerline, a dialogue box will appear asking the IRC code and design speed for which SE is to be created. Select the IRC code '99 for Expressway' and set the design speed to 100 km/h. Right-click to accept the settings. SE is created for the centerline as shown in figure 3.7. the green outlining is the SE section created by the software for specified conditions.

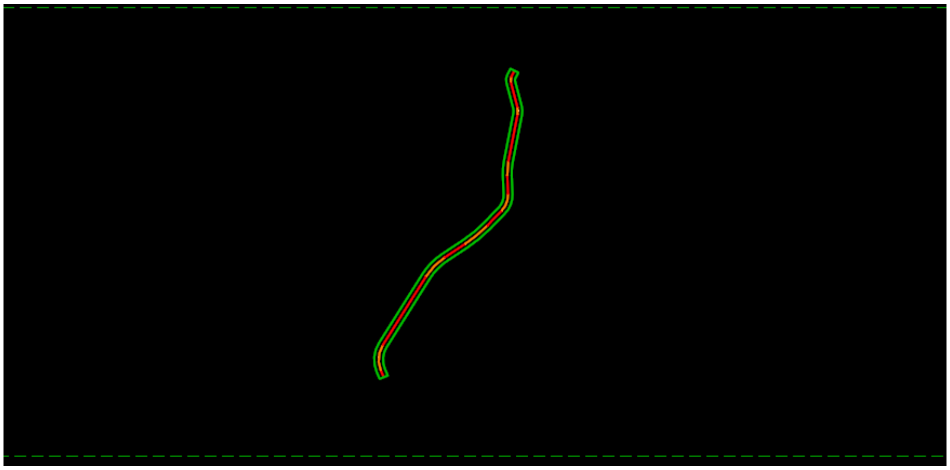


Fig. 3.7 SE along the centerline of E

9. After the addition of SE software will ask for the road template to be selected to form the different lanes along with the centerline. Select the Indian library and select the template 'IND_4Lane+ES'.[24]
10. Select create SE lanes and locate the SE section. A yellow and green colored lane will be created. The sections with error will be shown in orange color and the safe sections will be green in color as in figure 3.8. the sections where speed could be increased are n blue color.

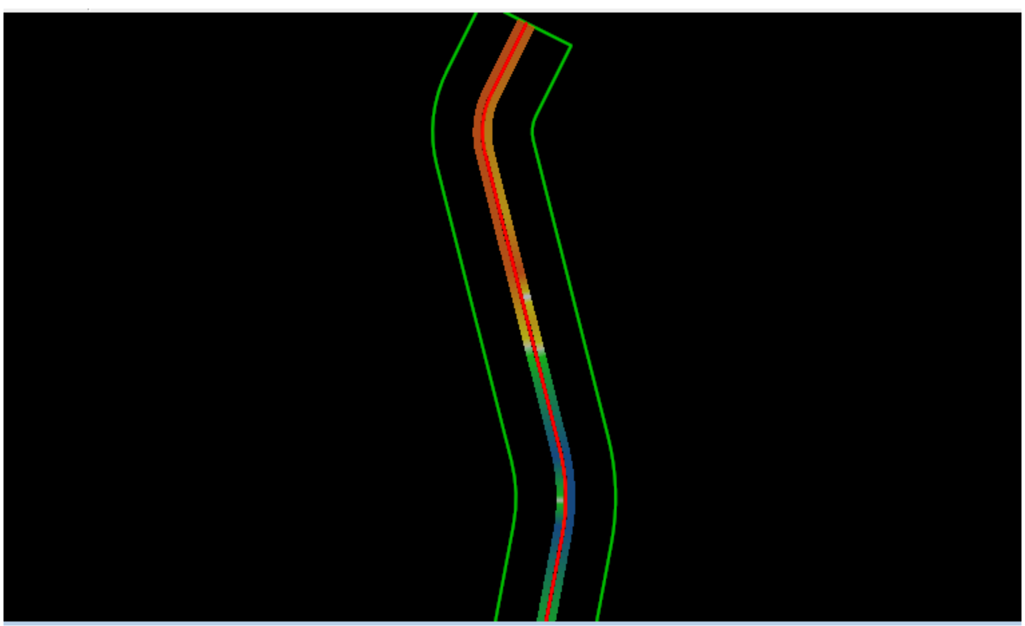


Fig. 3.8 The SE section of E

11. The corridor is created after the SE lanes are analyzed. Select 'New Corridor' under the 'Create' ribbon in the corridor tab. Select the active profile and locate the corridor baseline. Select the feature definition as 'Geom_base line' set the start and endpoint, the desired section where the corridor is to be added. After the corridor is created a road will be visible and the green line of SE will turn red as in figure 3.9

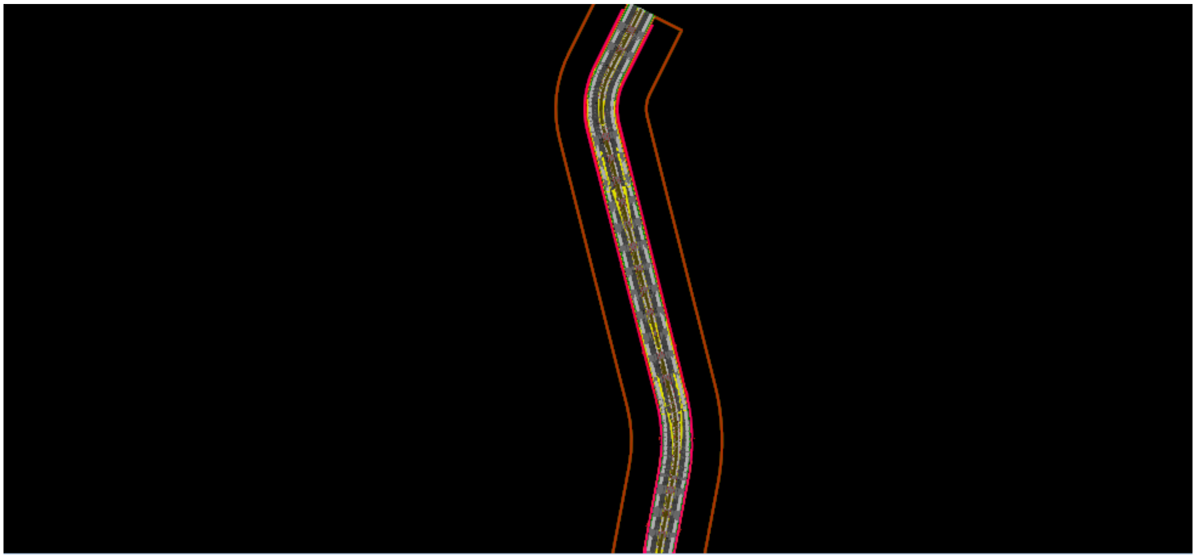


Fig. 3.9 Corridor created for alignment E

12. After creating the corridor, pavement details are to be added. Select create 'New Template Drop' from the same tab corridor was created. Select the template same as used for SE section lanes. Lock the start and end stations for the road alignment. The pavement detail is in figure 3.10.
13. The alignment is ready for analysis. The above steps have to be done again to create the modified alignments. 2 more alignments are designed. One with straighter sections and same curve radius as existing alignment named as M1 and the other alignment with increased curve radius named as M2

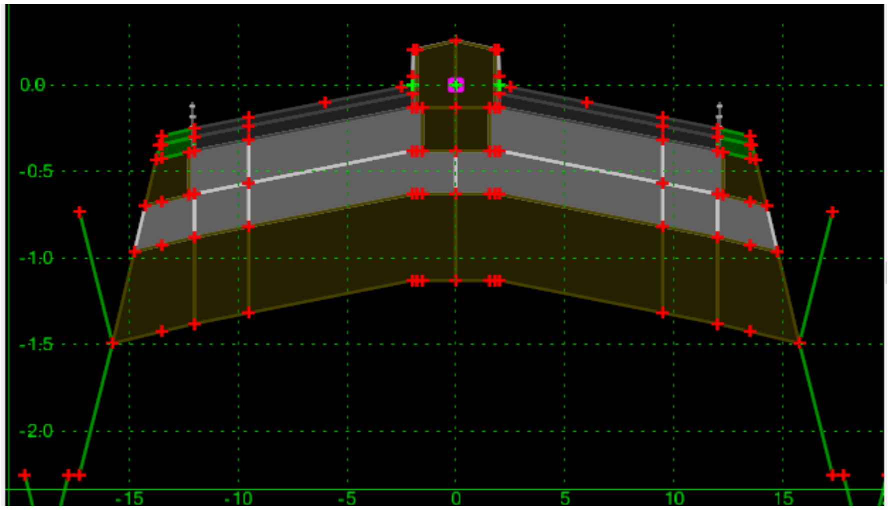


Fig. 3.10 Detailed pavement design used in alignment

The created alignment can be checked for the proper position, whether it is coinciding or not with the actual existing alignment. Go to the 'Level Display Manager' in the home tab and enable the lines and level color of the terrain. As these features turn on the designed road will display overlapping the existing road as in figure 3.11. Hence the coordinates of actual alignment on the ground and the alignment designed in software, match and can say that the software is precise.

Fig. 3.11 Matching the alignment E with the actual road map

3.10 Software outputs for modified alignments

1. All the steps are repeated to create a new modified alignment. First, the modified alignment with straighter sections(M1) is designed. Figure 3.12 shows the modified horizontal alignment. Modified alignment with increased curve radius(M2) is also created as in figure 3.13

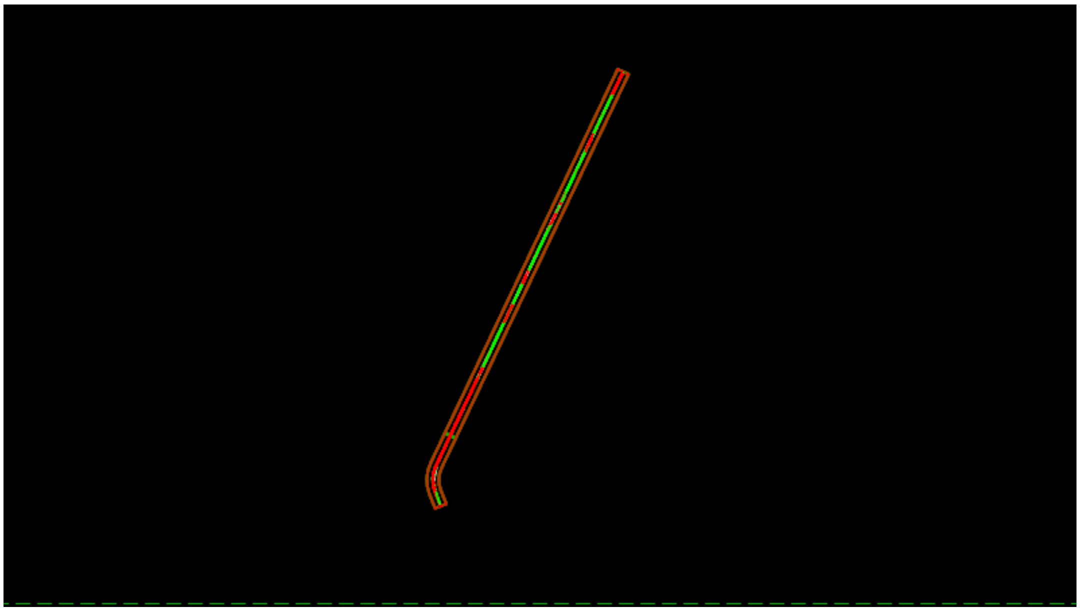


Fig. 3.12 Modified alignment (M1)

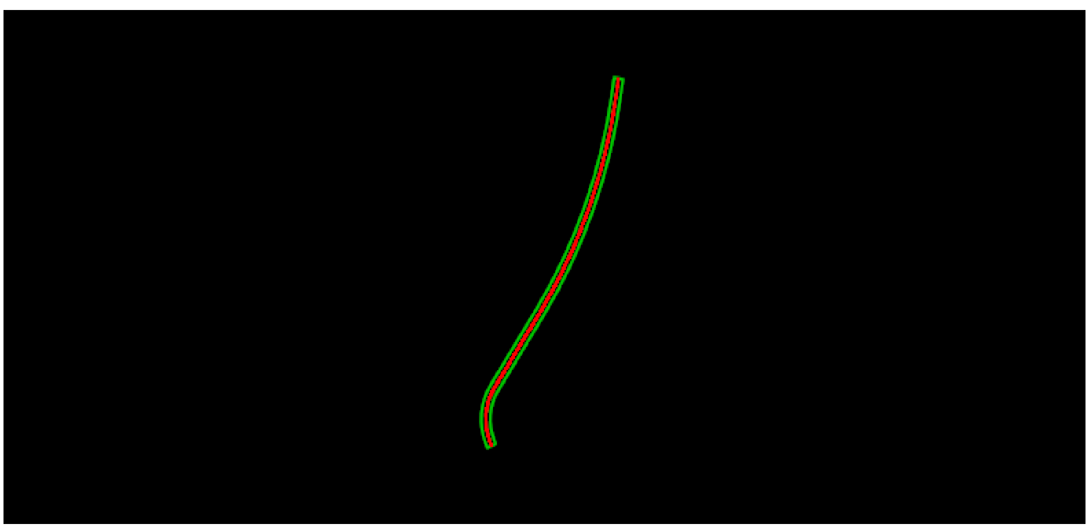


Fig 3.13 Modified alignment (M2)

2. Setting the active terrain modal, the vertical profile is created as in figure 3.14 for M1. The cutting volume in alignment M1 is high which would result in increasing overall cost. In

figure 3.15 the vertical profile for alignment M2 s shown. The cutting and filling volume is almost equal which could result in lowering the cost of alignment.

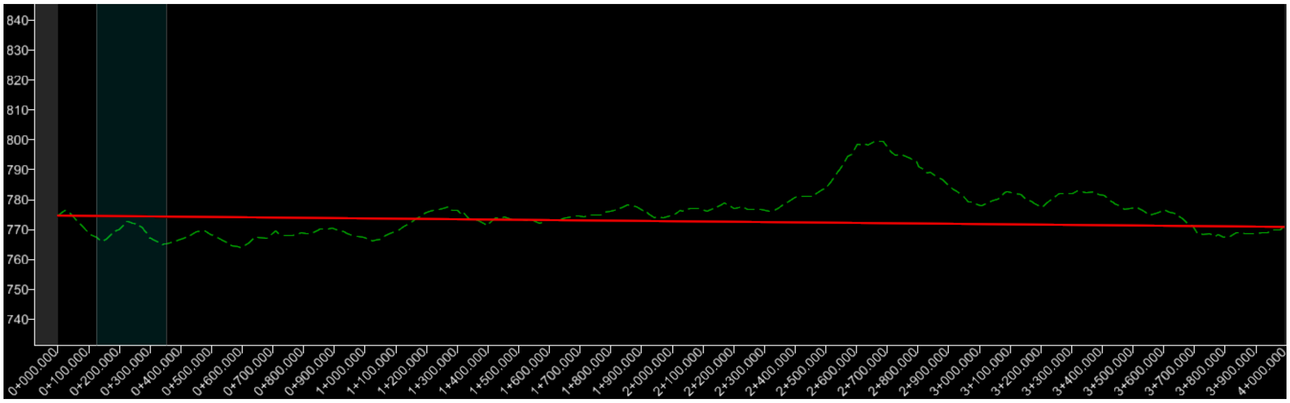


Fig. 3.14 Vertical alignment of M1

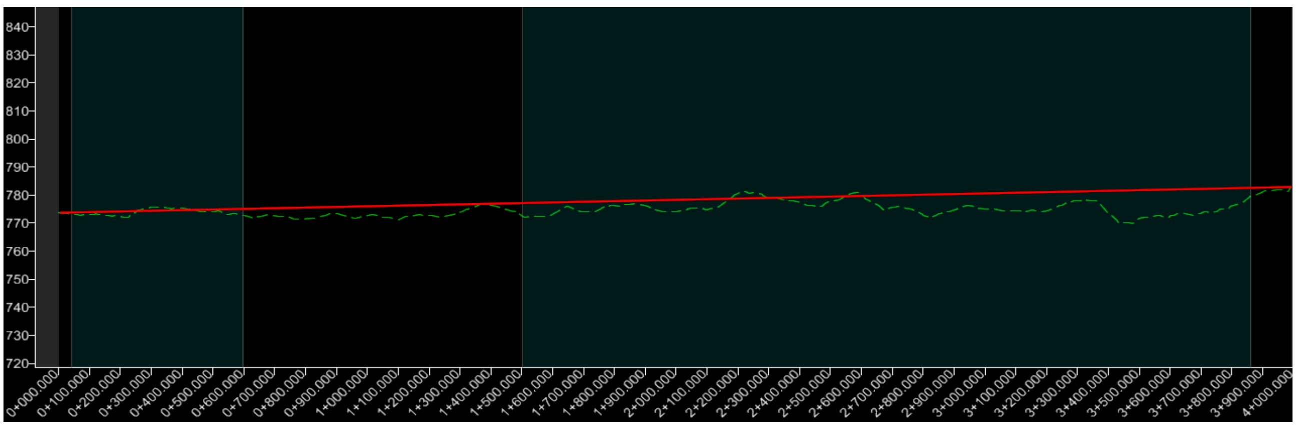
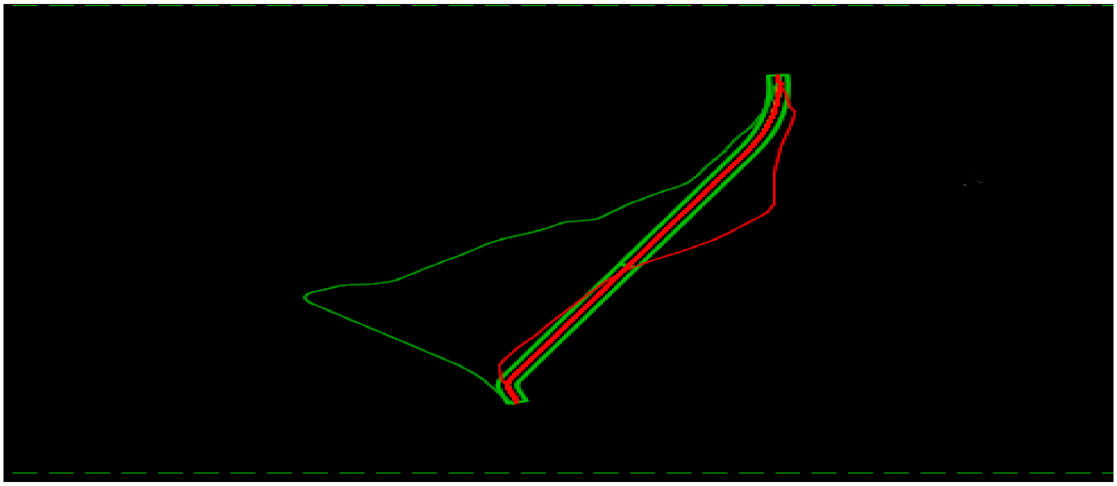


Fig. 3.15 Vertical alignment of M2

3. The pavement template used in the alignments (M1 and M2) is the same is used for the existing alignment(E). Selecting the same pavement template SE sections, SE lanes, and corridors are designed for both alignments. Coordinates of both alignments are locked at start and endpoints. The placing of both modified alignments is checked concerning the existing alignment and is shown in Figures 3.16(M1) and 3.17(M2).



. Fig. 3.16 Placing of M1 concerning E

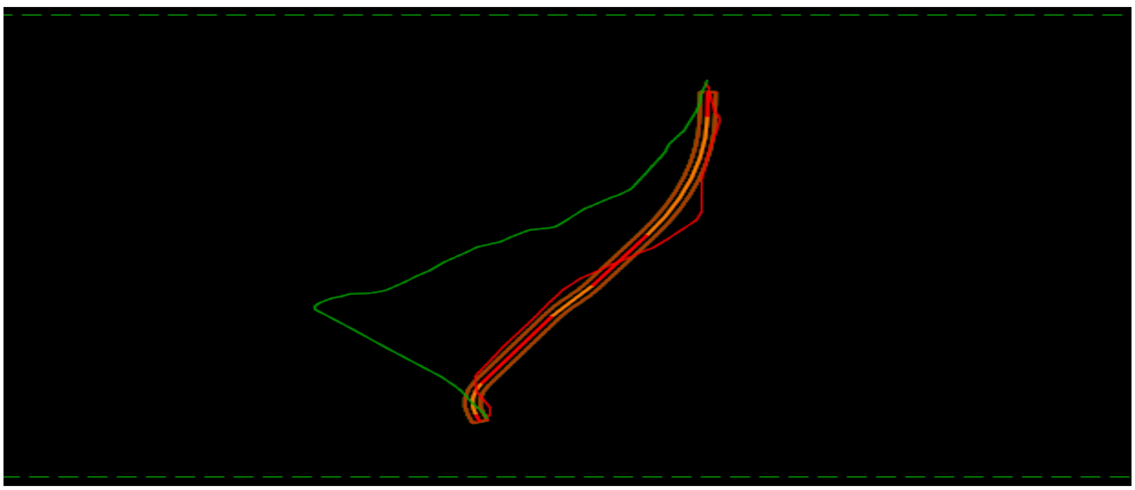


Fig. 3.17 Placing of M2 concerning E

3.11 Software outputs for various analysis of alignment

1. The alignments are checked for various aspects while designing. Figure 3.18, 3.19, 3.20 shows the errors of the horizontal alignment in E, M1, and M2 respectively. From the geometry tab, open the 'Table Editor' tool under the common tools ribbon. Select the centerline of the alignment to be analyzed. The analysis is done for a design speed of 100km/h. As in fig. 3.18 the alignment E has errors in total 4 curves, fig 3.19 of alignment M1 also show error in 1 curve and the alignment M2 do not show any error but gives a warning only as in fig. 3.20.

Station	Back Tangent Length	Back Bearing	Back Spiral Length	Northing	Easting	Radius	Arc Length	Design Speed	Ahead Spiral Length	Ahead Bearing	Ahead Tangent Length
0+000.000				3497497.69872	682544.10583					337°48'48.5"	86.64441
0+242.323	86.64441	157°48'48.5"	0.00000	3497733.46469	682447.95616	334.65577	311.35710	100.00000	0.00000	31°07'13.2"	943.57480
1+495.525	943.57480	211°07'13.2"	0.00000	3498818.84206	683103.22290	727.03864	307.89755	100.00000	0.00000	55°23'05.4"	279.63519
2+094.113	279.63519	235°23'05.4"	0.00000	3499160.58133	683598.32161	1512.63711	330.00762	100.00000	0.00000	42°53'05.2"	239.38625
2+604.021	239.38625	222°53'05.2"	0.00000	3499538.93755	683949.72458	268.21173	211.03685	100.00000	0.00000	357°48'010.0"	222.48187
3+014.621	222.48187	177°48'010.0"	0.00000	3499955.38163	683933.74663	736.69906	165.19780	100.00000	0.00000	10°39'02.9"	565.21198
3+705.656	565.21198	190°39'02.9"	0.00000	3500635.53253	684061.65784	199.35850	86.44997	100.00000	0.00000	345°48'18.1"	305.89623
4+085.417	305.89623	165°48'18.1"	0.00000	3501005.69248	683968.02754	85.96842	61.27934	100.00000	0.00000	26°38'46.2"	78.63979
4+194.697	78.63979	206°38'46.2"		3501104.58738	684017.65011						

Fig. 3.18 Horizontal alignment errors for E

Station	Back Tangent Length	Back Bearing	Back Spiral Length	Northing	Easting	Radius	Arc Length	Design Speed	Ahead Spiral Length	Ahead Bearing	Ahead Tangent Length
0+000.000				3497370.74599	682587.47143					342°37'13.4"	153.70386
0+209.303	153.70386	162°37'13.4"	0.00000	3497573.18768	682524.10915	146.73021	111.19773	100.00000	0.00000	26°02'28.7"	2863.2454
3+574.476	2863.24542	206°02'28.7"	0.00000	3500608.99327	684007.48073	1677.73436	892.65717	100.00000	0.00000	355°33'23.2"	0.00000
4+020.804	0.00000	175°33'23.2"		3501064.78378	683972.06106						

Fig. 3.19 Horizontal alignment errors for M1

Station	Back Tangent Length	Back Bearing	Back Spiral Length	Northing	Easting	Radius	Arc Length	Design Speed	Ahead Spiral Length	Ahead Bearing	Ahead Tangent Length
0+000.000				3497427.61098	682587.13402					335°57'56.9"	42.48305
0+320.320	42.48305	155°57'56.9"	0.00000	3497744.40413	682445.86201	547.92545	555.67292	100.00000	0.00000	34°04'18.2"	905.21866
2+682.770	905.21866	214°04'18.2"	0.00000	3499739.84458	683795.44115	5285.11495	2358.79172	100.00000	0.00000	08°30'00.5"	130.53107
3+992.697	130.53107	188°30'00.5"		3501055.13833	683992.01623						

Fig 3.20 Horizontal alignment warnings for M2

2. The SEs sections provided are also analyzed for all alignment while designing. In the corridor tab, there is an option to calculate SEs under the SEs ribbon. Select that feature and mark the SE sections and set the standards for which the analysis has to be done for the alignments. The analysis is done for 100km/h design speed according to IRC SP 99. Figures 13.21, 13.22, and 13.23 show the SEs table for E, M1, and M2 alignments respectively.

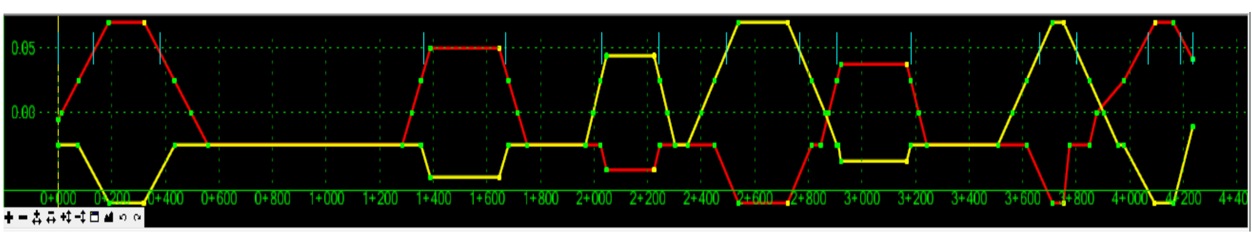


Fig 3.21 SE section for E

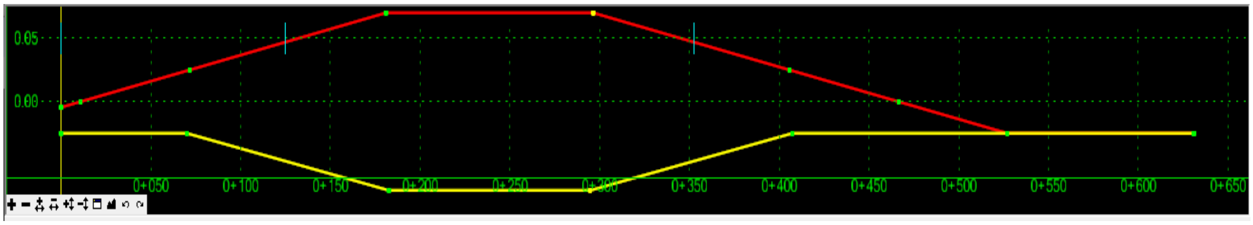


Fig 3.22 SE section for M1

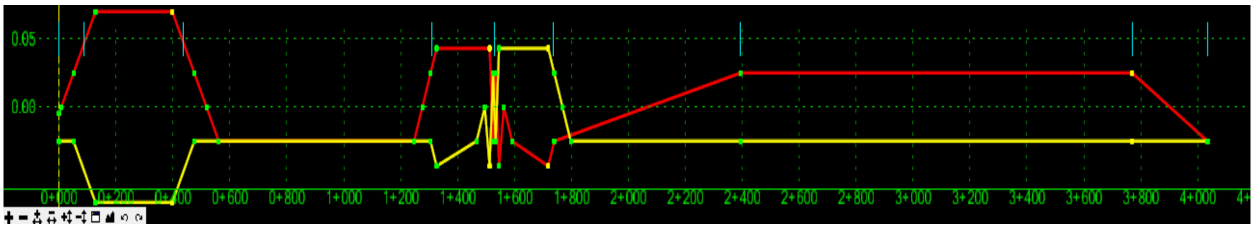


Fig. 3.23 SE section for M2

3. After the completion of designing the whole alignment go to the ‘Corridor’ tab and under the ‘Review’ ribbon select ‘Corridor Reports’. It will automatically take all design aspects under consideration and will calculate the quantities of the various material used in the whole project. There is a ‘unit price’ column in the quantity dialogue box. The unit price is set to 1 by default. Figures 3.24, 3.25, and 3.26 show the quantity details and allow the addition of unit price of different materials of the alignments E, M1, and M2. The unit price has to be added in this tab only and reports are generated.

Material	Surface Area	Volume	Units	Unit Cost	Total Cost/Material
Cut Volume	0.0000	221517.1481	CuM	115.00	25474472.03
Fill Volume	0.0000	781113.1183	CuM	190.00	148411492.48
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Bituminuous Concrete (BC)	0.0000	4192.0876	CuM	920.00	3856720.59
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Dense Bituminous Macadam (DBM)	0.0000	6707.3402	CuM	760.00	5097578.55
Mesh\2_Aggregate & Soil (IRC:37-2018)\Granular Sub Base (GSB)	0.0000	30413.5959	CuM	900.00	27372236.31
Mesh\2_Aggregate & Soil (IRC:37-2018)\Subgrade	0.0000	63971.2575	CuM	215.00	13753820.36
Mesh\2_Aggregate & Soil (IRC:37-2018)\Wet Mix Macadam (WMM)	0.0000	22436.5142	CuM	975.00	21875601.35
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Conc Misc	0.0000	34.4185	CuM	400.00	13767.40
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Curb	0.0000	755.7788	CuM	370.00	279638.16
Mesh\Asphalt\TC_Asph Conc Wearing Cse	1089.9428	0.0000	SqM	32.00	34878.17
Mesh\Grading\TC_Cutslope	33583.6812	0.0000	SqM	195.00	6548817.83
Mesh\Grading\TC_Ditch	16565.8255	0.0000	SqM	40.00	662633.02
Mesh\Grading\TC_Earth Shoulder	0.0000	1776.6067	CuM	215.00	381970.44
Mesh\Grading\TC_Fillslope	72128.0341	0.0000	SqM	90.00	6491523.07
Mesh\Grading\TC_Topsoil	0.0000	12351.3406	CuM	190.00	2346754.71

eport　Total Estimated Cost: 262601904.47

Fig. 3.24 Quantity and cost estimations of alignment E

Material	Surface Area	Volume	Units	Unit Cost	Total Cost/Material
Cut Volume	0.0000	38729.0401	CuM	115.00	4453839.61
Fill Volume	0.0000	967706.8736	CuM	190.00	183864305.98
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Bituminous Concrete (BC)	0.0000	4020.8042	CuM	920.00	3699139.85
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Dense Bituminous Macadam (DBM)	0.0000	6433.2867	CuM	760.00	4889297.90
Mesh\2_Aggregate & Soil (IRC:37-2018)\Granular Sub Base (GSB)	0.0000	29170.9344	CuM	900.00	26253840.96
Mesh\2_Aggregate & Soil (IRC:37-2018)\Subgrade	0.0000	61357.4719	CuM	215.00	13191856.47
Mesh\2_Aggregate & Soil (IRC:37-2018)\Wet Mix Macadam (WMM)	0.0000	21519.7863	CuM	975.00	20981791.66
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Conc Misc	0.0000	33.0122	CuM	400.00	13204.87
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Curb	0.0000	662.2812	CuM	370.00	245044.06
Mesh\Asphalt\TC_Asph Conc Wearing Cse	1045.4091	0.0000	SqM	32.00	33453.09
Mesh\Grading\TC_Cutslope	7673.5277	0.0000	SqM	195.00	1496337.90
Mesh\Grading\TC_Ditch	20236.9824	0.0000	SqM	40.00	809479.30
Mesh\Grading\TC_Earth Shoulder	0.0000	1704.0168	CuM	215.00	366363.62
Mesh\Grading\TC_Fillslope	85831.2215	0.0000	SqM	90.00	7724809.93
Mesh\Grading\TC_Topsoil	0.0000	11846.6802	CuM	190.00	2250869.25

port

Total Estimated Cost: 270273634.45

Fig. 3.25 Quantity and cost estimations of alignment M1

Material	Surface Area	Volume	Units	Unit Cost	Total Cost/Material
Cut Volume	0.0000	425596.8855	CuM	115.00	48943641.83
Fill Volume	0.0000	54665.5076	CuM	190.00	10386446.44
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Bituminous Concrete (BC)	0.0000	4034.4217	CuM	920.00	3711667.95
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Dense Bituminous Macadam (DBM)	0.0000	6455.0747	CuM	760.00	4905856.77
Mesh\2_Aggregate & Soil (IRC:37-2018)\Granular Sub Base (GSB)	0.0000	29269.7293	CuM	900.00	26342756.41
Mesh\2_Aggregate & Soil (IRC:37-2018)\Subgrade	0.0000	61565.2750	CuM	215.00	13236534.11
Mesh\2_Aggregate & Soil (IRC:37-2018)\Wet Mix Macadam (WMM)	0.0000	21592.6687	CuM	975.00	21052851.94
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Conc Misc	0.0000	33.1240	CuM	400.00	13249.59
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Curb	0.0000	776.3598	CuM	370.00	287253.13
Mesh\Asphalt\TC_Asph Conc Wearing Cse	1048.9496	0.0000	SqM	32.00	33566.39
Mesh\Grading\TC_Cutslope	48622.0806	0.0000	SqM	195.00	9481305.72
Mesh\Grading\TC_Ditch	4132.9059	0.0000	SqM	40.00	165316.23
Mesh\Grading\TC_Earth Shoulder	0.0000	1709.7879	CuM	215.00	367604.40
Mesh\Grading\TC_Fillslope	5778.6784	0.0000	SqM	90.00	520081.06
Mesh\Grading\TC_Topsoil	0.0000	11886.8021	CuM	190.00	2258492.40

eport

Total Estimated Cost: 141706624.37

Fig. 3.26 Quantity and cost estimations of alignment M2

All the alignments are created successfully and the various reports are generated. The reports created areas

1. Detailed horizontal alignment report of all alignments created.
2. Detailed vertical alignment report of the created alignments
3. Detailed SE reports
4. Detailed quantity and costing reports.[25]

CHAPTER-4
RESULT AND DISCUSSION

4.1 General

Survey data is extracted successfully from google earth and the terrain file is created in global mapper with all major and minor contours. The terrain file is successfully imported to OpenRoads software with all the features of the ground profile like existing roads, buildings, highest and lowest level points, tree points, marshy lands and elevations, and depression in ground condition. Highway design and pavement profile are taken by the IL&FS construction company for reference. The actual unit price is also taken from the company itself just to check the precision of the software, whether the actual cost of the structure is similar to the cost estimated by the software of the alignment E.

4.2 Various design results

1. Horizontal alignment analysis of the existing and modified alignments

Table 4.1 Detailed analysis of horizontal design of alignment E

Point	Easting (X)	Northing (Y)	Station	Direction	Radius
1	682544.106	3497497.699	0.000	N22.187°W	
2	682511.387	3497577.928	86.644	N22.187°W	
3	682511.387	3497577.928	86.644	N22.187°W	334.656
4	682534.771	3497877.264	398.002	N22.187°W	334.656
5	682534.771	3497877.264	398.002	N31.120°E	
6	683022.446	3498685.043	1341.576	N31.120°E	
7	683022.446	3498685.043	1341.576	N31.120°E	727.039
8	683231.849	3498907.625	1649.474	N31.120°E	727.039
9	683231.849	3498907.625	1649.474	N55.385°E	

10	683461.985	3499066.475	1929.109	N55.385°E	
11	683461.985	3499066.475	1929.109	N55.385°E	-1512.637
12	683711.059	3499281.965	2259.117	N55.385°E	-1512.637
13	683711.059	3499281.965	2259.117	N42.885°E	
14	683873.967	3499457.369	2498.503	N42.885°E	
15	683873.967	3499457.369	2498.503	N42.885°E	-268.212
16	683945.457	3499650.178	2709.540	N42.885°E	-268.212
17	683945.457	3499650.178	2709.540	N2.197°W	
18	683936.927	3499872.496	2932.022	N2.197°W	
19	683936.927	3499872.496	2932.022	N2.197°W	736.699
20	683949.077	3500036.899	3097.219	N2.197°W	736.699
21	683949.077	3500036.899	3097.219	N10.651°E	
22	684053.541	3500592.374	3662.431	N10.651°E	
23	684053.541	3500592.374	3662.431	N10.651°E	-199.359
24	684050.889	3500678.107	3748.881	N10.651°E	-199.359
25	684050.889	3500678.107	3748.881	N14.195°W	
26	683975.876	3500974.663	4054.778	N14.195°W	
27	683975.876	3500974.663	4054.778	N14.195°W	85.968
28	683982.382	3501034.300	4116.057	N14.195°W	85.968
29	683982.382	3501034.300	4116.057	N26.646°E	
30	684017.650	3501104.587	4194.697	N26.646°E	

Table 4.2 Detailed analysis of horizontal design of alignment M1

Point	Easting (X)	Northing (Y)	Station	Direction	Radius
1	682559.662	3497507.069	0.000	N21.680°W	
2	682513.535	3497623.098	124.861	N21.680°W	
3	682513.535	3497623.098	124.861	N21.680°W	277.139
4	682520.682	3497844.277	352.502	N21.680°W	277.139
5	682520.682	3497844.277	352.502	N25.382°E	
6	684080.717	3501132.378	3991.914	N25.382°E	

Table 4.3 Detailed analysis of horizontal design of alignment M2

Point	Easting (X)	Northing (Y)	Station	Direction	Radius
1	682582.462	3497448.530	0.000	N25.336°W	
2	682540.438	3497537.291	98.207	N25.336°W	
3	682540.438	3497537.291	98.207	N25.336°W	400.000
4	682566.115	3497925.726	504.765	N25.336°W	400.000
5	682566.115	3497925.726	504.765	N32.900°E	
6	683579.211	3499491.755	2369.922	N32.900°E	
7	683579.211	3499491.755	2369.922	N32.900°E	-2323.920
8	683944.101	3500563.651	3513.734	N32.900°E	-2323.920
9	683944.101	3500563.651	3513.734	N4.699°E	
10	683982.037	3501025.152	3976.791	N4.699°E	

The above three tables give a detailed report of the horizontal alignments designed in the software. The minus sign indicates the left curve and the positive indicates the right turn. The radius highlighted with red color in E and M1 alignments is the errors given by the software. These errors can be eliminated either by decreasing design speed or by increasing the curve radius. Decreasing design speed is against the objectives of the study hence increasing curve radius to safe parameters is practiced in the M2 alignment, the radius of the important curves is increased which removes the error from the alignment even at 100km/h design speed. In table 4 only one radius became yellow, which means the curve radius can be increased more to achieve a design speed of more than 100km/h.

2. Vertical alignment analysis of the existing and modified alignments

Table 4.4 Analysis of vertical design of alignment E

	Station	**Elevation**	**Northing**	**Easting**
Element: Linear				
START	0.000	773.179	3497497.699	682544.106
END	4194.697	781.511	3501104.587	684017.650
Tangent Grade:	0.002			
Tangent Length:	4194.697			

Table 4.5 Analysis of vertical design of alignment M1

	Station	**Elevation**	**Northing**	**Easting**
Element: Linear				
START	0.000	774.689	3497507.069	682559.662
END	3992.534	770.900	3501114.075	684113.570

Table 4.6 Analysis of vertical design of alignment M2

	Station	Elevation	Northing	Easting
Element: Linear				
START	4.426	773.750	3497431.654	682585.331
END	3992.823	782.917	3512472.786	685218.420
Tangent Grade:	0.002			
Tangent Length:	3988.397			

The tables 5,6 and 7 gives the detail about the vertical alignment. There are no such errors in the alignment as the gradient does not vary much. This is also clear from fig. 3.6, 3.14, and 3.15, that the ground profile is stable and the vertical profile can be obtained by using only a single linear element. The report will automatically detect errors when the gradient is high and the proper curve is not provided at the points having higher elevations.

3. Detailed SEs report of the alignments E, M1, and M2

Table 4.7 SE details of alignment E LEFT LANE

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Start Point	0.000	0.000	0.004	0.004	334.656
Reverse Crown	42.844	42.844	0.025	0.025	334.656
Full Super	132.844	132.844	0.070	0.070	334.656
Full Super	351.802	351.802	0.070	0.070	334.656

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Reverse Crown	441.802	441.802	0.025	0.025	334.656
Level Crown	491.802	491.802	0.000	0.000	334.656
Normal Crown	541.802	541.802	-0.025	-0.025	334.656
Normal Crown	1265.526	1265.526	-0.025	-0.025	334.656
Level Crown	1298.026	1298.026	0.000	0.000	334.656
Reverse Crown	1330.526	1330.526	0.025	0.025	334.656
Full Super	1363.026	1363.026	0.050	0.050	334.656
Full Super	1628.024	1628.024	0.050	0.050	334.656
Reverse Crown	1660.524	1660.524	0.025	0.025	334.656
Level Crown	1693.024	1693.024	0.000	0.000	334.656
Normal Crown	1725.524	1725.524	-0.025	-0.025	334.656
Normal Crown	1935.421	1935.421	-0.025	-0.025	334.656
Full Super	1940.659	1940.659	-0.029	-0.029	334.656
Full Super	2247.567	2247.567	-0.029	-0.029	334.656
Normal Crown	2252.805	2252.805	-0.025	-0.025	334.656

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Normal Crown	2442.189	2442.189	-0.025	-0.025	334.656
Full Super	2557.903	2557.903	-0.070	-0.070	334.656
Full Super	2650.140	2650.140	-0.070	-0.070	334.656
Normal Crown	2765.854	2765.854	-0.025	-0.025	334.656
Normal Crown	2855.972	2855.972	-0.025	-0.025	334.656
Level Crown	2888.472	2888.472	0.000	0.000	334.656
Reverse Crown	2920.972	2920.972	0.025	0.025	334.656
Full Super	2953.472	2953.472	0.050	0.050	334.656
Full Super	3075.769	3075.769	0.050	0.050	334.656
Reverse Crown	3108.269	3108.269	0.025	0.025	334.656
Level Crown	3140.769	3140.769	0.000	0.000	334.656
Normal Crown	3173.269	3173.269	-0.025	-0.025	334.656
Normal Crown	3505.256	3505.256	-0.025	-0.025	334.656
Normal Crown	3587.346	3587.346	-0.025	-0.025	334.656
Full Super	3669.681	3669.681	-0.070	-0.070	334.656

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Level Crown	3696.328	3696.328	0.000	0.000	334.656
Full Super	3741.631	3741.631	-0.070	-0.070	334.656
Normal Crown	3823.967	3823.967	-0.025	-0.025	334.656
Reverse Crown	3887.399	3887.399	0.025	0.025	334.656
Full Super	3939.507	3939.507	0.070	0.070	334.656
End Point	4194.697	4194.697	0.070	0.070	334.656

Table 4.8 SE details of alignment E RIGHT LANE

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Start Point	0.000	0.000	-0.005	-0.005	334.656
Normal Crown	41.280	41.280	-0.025	-0.025	334.656
Full Super	134.494	134.494	-0.070	-0.070	334.656
Full Super	350.152	350.152	-0.070	-0.070	334.656
Normal Crown	443.366	443.366	-0.025	-0.025	334.656

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Normal Crown	1330.526	1330.526	-0.025	-0.025	334.656
Full Super	1363.026	1363.026	-0.050	-0.050	334.656
Full Super	1628.024	1628.024	-0.050	-0.050	334.656
Normal Crown	1660.524	1660.524	-0.025	-0.025	334.656
Normal Crown	1875.796	1875.796	-0.025	-0.025	334.656
Level Crown	1905.659	1905.659	0.000	0.000	334.656
Reverse Crown	1935.523	1935.523	0.025	0.025	334.656
Full Super	1940.659	1940.659	0.029	0.029	334.656
Full Super	2247.567	2247.567	0.029	0.029	334.656
Reverse Crown	2252.703	2252.703	0.025	0.025	334.656
Level Crown	2282.567	2282.567	0.000	0.000	334.656
Normal Crown	2312.430	2312.430	-0.025	-0.025	334.656
Normal Crown	2318.753	2318.753	-0.025	-0.025	334.656
Level Crown	2381.253	2381.253	0.000	0.000	334.656
Reverse Crown	2443.753	2443.753	0.025	0.025	334.656

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Full Super	2556.253	2556.253	0.070	0.070	334.656
Full Super	2651.790	2651.790	0.070	0.070	334.656
Reverse Crown	2764.290	2764.290	0.025	0.025	334.656
Level Crown	2826.790	2826.790	0.000	0.000	334.656
Normal Crown	2889.290	2889.290	-0.025	-0.025	334.656
Normal Crown	2920.972	2920.972	-0.025	-0.025	334.656
Full Super	2953.472	2953.472	-0.050	-0.050	334.656
Full Super	3075.769	3075.769	-0.050	-0.050	334.656
Normal Crown	3108.269	3108.269	-0.025	-0.025	334.656
Normal Crown	3421.053	3421.053	-0.025	-0.025	334.656
Level Crown	3504.981	3504.981	0.000	0.000	334.656
Reverse Crown	3588.910	3588.910	0.025	0.025	334.656
Full Super	3671.331	3671.331	0.070	0.070	334.656
Full Super	3739.981	3739.981	0.070	0.070	334.656
Reverse Crown	3822.403	3822.403	0.025	0.025	334.656

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Normal Crown	3878.013	3878.013	-0.025	-0.025	334.656
Level Crown	3906.331	3906.331	0.000	0.000	334.656
Full Super	3929.607	3929.607	-0.070	-0.070	334.656
Normal Crown	3990.260	3990.260	-0.025	-0.025	334.656
End Point	4194.697	4194.697	-0.062	-0.062	334.656

Table 4.9 SE details of alignment M1 LEFT LANE

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Start Point	0.000	0.000	-0.005	-0.005	277.139
Level Crown	10.961	10.961	0.000	0.000	277.139
Reverse Crown	71.676	71.676	0.025	0.025	277.139
Full Super	180.961	180.961	0.070	0.070	277.139
Full Super	296.402	296.402	0.070	0.070	277.139
Reverse Crown	405.688	405.688	0.025	0.025	277.139

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Level Crown	466.402	466.402	0.000	0.000	277.139
Normal Crown	527.116	527.116	-0.025	-0.025	277.139
Normal Crown	630.923	630.923	-0.025	-0.025	277.139

Table 4.10 SE details of alignment M1 RIGHT LANE

Point Type	Station [Defined]	Station [Standards]	Cross Slope [Defined]	Cross Slope [Standards]	Radius
Normal Crown	0.000	0.000	-0.025	-0.025	277.139
Normal Crown	70.111	70.111	-0.025	-0.025	277.139
Full Super	182.611	182.611	-0.070	-0.070	277.139
Full Super	294.752	294.752	-0.070	-0.070	277.139
Normal Crown	407.252	407.252	-0.025	-0.025	277.139
Normal Crown	630.923	630.923	-0.025	-0.025	277.139

Table 4.11 SE details of alignment M2 LEFT LANE

Station	Cross Slope	Mode	Delta G
0.000	-0.010	Start Point	
17.807	0.000	Level Crown	0.001
60.664	0.025	Reverse Crown	0.001
137.807	0.070	Full Super	0.001
465.165	0.070	Full Super	
542.308	0.025	Reverse Crown	-0.001
585.165	0.000	Level Crown	-0.001
628.022	-0.025	Normal Crown	-0.001
1437.343	-0.025	Normal Crown	

From table 4.8 to table 4.12, all are the detailed reports of the SE sections that are created along the 3 alignments E, M1, and M2. The maximum number of SE sections are in alignment E. that is because the original alignment has a lot of curves. Maximum SE is provided at various curves in each alignment. This is because of the stabilized design speed that is provided along the curves too. The curves where the maximum cross slope is provided, design speed at these curves is 100km/h maximum, to increase the design speed of those curves, increased curve radius may be helpful.

Table 4.12 SE details of alignment M2 RIGHT LANE)

Station	Cross Slope	Mode	Delta G
0.000	-0.025	Normal Crown	
60.664	-0.025	Normal Crown	
137.807	-0.070	Full Super	-0.001
465.165	-0.070	Full Super	
542.308	-0.025	Normal Crown	0.001
1437.343	-0.025	Normal Crown	

4. Quantities and cost estimation report of various alignments (E, M1 and M2)

Table 4.13 Detailed cost estimation with quantities of alignment E

Material	Component Volume Totals	Component Surface Area Totals	Unit Cost	Material Cost
Cut Volume	221517.148		115.00	25474472.030
Fill Volume	781113.118		190.00	148411492.473
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Bituminous Concrete (BC)	4192.088		920.00	3856720.638
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Dense Bituminous Macadam (DBM)	6707.340		760.00	5097578.582
Mesh\2_Aggregate & Soil (IRC:37-2018)\Granular Sub Base (GSB)	30413.596		900.00	27372236.309
Mesh\2_Aggregate & Soil (IRC:37-2018)\Subgrade	63971.258		215.00	13753820.370

Material	Component Volume Totals	Component Surface Area Totals	Unit Cost	Material Cost
Mesh\2_Aggregate & Soil (IRC:37-2018)\Wet Mix Macadam (WMM)	22436.514		975.00	21875601.375
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Conc Misc	34.418		400.00	13767.384
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Curb	755.779		370.00	279638.160
Mesh\Asphalt\TC_Asph Conc Wearing Cse		1089.943	32.00	34878.169
Mesh\Grading\TC_Cutslope		33583.681	195.00	6548817.830
Mesh\Grading\TC_Ditch		16565.826	40.00	662633.021
Mesh\Grading\TC_Earth Shoulder	1776.607		215.00	381970.450
Mesh\Grading\TC_Fillslope		72128.034	90.00	6491523.068
Mesh\Grading\TC_Topsoil	12351.341		190.00	2346754.708
Total Estimated Cost:				**262601904.57**

Table 4.14 Detailed cost estimations and quantities of alignment M1

Material	Component Volume Totals	Component Surface Area Totals	Unit Cost	Material Cost
Cut Volume	38729.040		115.00	4453839.608
Fill Volume	967706.874		190.00	183864305.984
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Bituminous Concrete (BC)	4020.804		920.00	3699139.855

Material	Component Volume Totals	Component Surface Area Totals	Unit Cost	Material Cost
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Dense Bituminous Macadam (DBM)	6433.287		760.00	4889297.895
Mesh\2_Aggregate & Soil (IRC:37-2018)\Granular Sub Base (GSB)	29170.934		900.00	26253840.960
Mesh\2_Aggregate & Soil (IRC:37-2018)\Subgrade	61357.472		215.00	13191856.468
Mesh\2_Aggregate & Soil (IRC:37-2018)\Wet Mix Macadam (WMM)	21519.786		975.00	20981791.656
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Conc Misc	33.012		400.00	13204.866
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Curb	662.281		370.00	245044.057
Mesh\Asphalt\TC_Asph Conc Wearing Cse		1045.409	32.00	33453.091
Mesh\Grading\TC_Cutslope		7673.528	195.00	1496337.901
Mesh\Grading\TC_Ditch		20236.982	40.00	809479.297
Mesh\Grading\TC_Earth Shoulder	1704.017		215.00	366363.615
Mesh\Grading\TC_Fillslope		85831.221	90.00	7724809.932
Mesh\Grading\TC_Topsoil	11846.680		190.00	2250869.245
Total Estimated Cost:				**270273634.43**

Table 4.15 Detailed cost estimations and quantities of alignment M2

Material	Component Volume Totals	Component Surface Area Totals	Unit Cost	Material Cost
Cut Volume	425596.885		115.00	48943641.829

Material	Component Volume Totals	Component Surface Area Totals	Unit Cost	Material Cost
Fill Volume	54665.508		190.00	10386446.440
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Bituminous Concrete (BC)	4034.422		920.00	3711667.952
Mesh\1_Asphalt/Flexible (IRC:37-2018)\Dense Bituminous Macadam (DBM)	6455.075		760.00	4905856.772
Mesh\2_Aggregate & Soil (IRC:37-2018)\Granular Sub Base (GSB)	29269.729		900.00	26342756.409
Mesh\2_Aggregate & Soil (IRC:37-2018)\Subgrade	61565.275		215.00	13236534.114
Mesh\2_Aggregate & Soil (IRC:37-2018)\Wet Mix Macadam (WMM)	21592.669		975.00	21052851.942
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Conc Misc	33.124		400.00	13249.588
Mesh\3_Concrete/Rigid (IRC :58-2015)\TC_Curb	776.360		370.00	287253.128
Mesh\Asphalt\TC_Asph Conc Wearing Cse		1048.950	32.00	33566.388
Mesh\Grading\TC_Cutslope		48622.081	195.00	9481305.717
Mesh\Grading\TC_Ditch		4132.906	40.00	165316.234
Mesh\Grading\TC_Earth Shoulder	1709.788		215.00	367604.401
Mesh\Grading\TC_Fillslope		5778.678	90.00	520081.059
Mesh\Grading\TC_Topsoil	11886.802		190.00	2258492.398
Total Estimated Cost:				**141706624.37**

The actual cost of the project was 26.64 CRs. according to the data collected from the company. The software's cost estimation for the existing alignment (E) designed in the software comes out to be 26.26 CRs. which is too close to the actual cost of the road alignment. This gives a good idea of the precision of the software, and the software is reliable. The modified alignment (M1) cost comes out to be 27.02 CRs. which is less than the actual cost. The cost of the modified alignment (M2) comes out to be 14.17 CRs. which is very less as compared to the actual cost. This is due to the low cut and fills volumes in this alignment.

The comparison of various properties is done in table 4.16.

Table 4.16 Collective comparison of different alignments

Alignment	Total Length KM	Safe design speed(km/h)	Total cut volume m^3	Total fill volume m^3	The total estimated cost of alignment (CRs.)
Actual	4.23	80-100	49580.4	1485265.24	26.64
E	4.23	80-100	47198.3	1434323.11	26.27
M1	3.97	100	1856883.8	217497.3	25.51
M2	4.02	100	408308.5	56774.2	16.63

5. A sight visibility test is also done in the software for the existing alignment (E). The chainage points that need to be redesigned are shown in the table. Sight visibility for other alignments was also done and both modified alignments M1 and M2 are safe and available sight distance is achieved throughout the stretch.

   Table 4.17 clearly shows that the existing alignment curves, within the chainage points 180+75 – 210+90, 230+25 - 270+15, and 340+95 - 370+65 should be redesigned as they failed to provide proper sight distance to the drive at a speed of 100km/h. If the design speed is reduced to 60km/h the sight distance is achieved but the design speed cannot be reduced as reducing design speed would fail one of the major objectives of the study so the curves should be redesigned by increasing curve radius or by providing widening on the curves.

Table 4.17 Sight visibility results for alignment E

Eye Position	Actual End Position	Object Position	Actual End Level	Design Speed	Achieved Distance	Achieved Chord Distance	Status	Surface Intersect
1860.000	2040.000	2040.000	776.146	100.000	180.000	180.020	Achieved	None
1875.000	**2045.327**	**2055.000**	**776.206**	**100.000**	**170.327**	**170.355**	**Not Achieved**	**Design**
1890.000	**2059.726**	**2070.000**	**776.219**	**100.000**	**169.726**	**169.773**	**Not Achieved**	**Design**
1905.000	**2073.942**	**2085.000**	**776.232**	**100.000**	**168.942**	**169.002**	**Not Achieved**	**Design**
1920.000	**2088.464**	**2100.000**	**776.245**	**100.000**	**168.464**	**168.529**	**Not Achieved**	**Design**
1935.000	**2102.716**	**2115.000**	**776.258**	**100.000**	**167.716**	**167.778**	**Not Achieved**	**Design**
1950.000	**2117.151**	**2130.000**	**776.271**	**100.000**	**167.151**	**167.206**	**Not Achieved**	**Design**
1965.000	**2131.681**	**2145.000**	**776.283**	**100.000**	**166.681**	**166.725**	**Not Achieved**	**Design**
1980.000	**2146.152**	**2160.000**	**776.295**	**100.000**	**166.152**	**166.184**	**Not Achieved**	**Design**
1995.000	**2160.986**	**2175.000**	**776.306**	**100.000**	**165.986**	**166.011**	**Not Achieved**	**Design**
2010.000	**2175.590**	**2190.000**	**776.317**	**100.000**	**165.590**	**165.615**	**Not Achieved**	**Design**
2025.000	**2190.478**	**2205.000**	**776.328**	**100.000**	**165.478**	**165.517**	**Not Achieved**	**Design**
2040.000	**2205.507**	**2220.000**	**776.337**	**100.000**	**165.507**	**165.555**	**Not Achieved**	**Design**
2055.000	**2220.459**	**2235.000**	**776.347**	**100.000**	**165.459**	**165.506**	**Not Achieved**	**Design**
2070.000	**2235.912**	**2250.000**	**776.354**	**100.000**	**165.912**	**165.965**	**Not Achieved**	**Design**
2085.000	**2252.016**	**2265.000**	**776.358**	**100.000**	**167.016**	**167.077**	**Not Achieved**	**Design**
2100.000	**2268.035**	**2280.000**	**776.362**	**100.000**	**168.035**	**168.107**	**Not Achieved**	**Design**
2115.000	**2283.815**	**2295.000**	**776.368**	**100.000**	**168.815**	**168.899**	**Not Achieved**	**Design**
2130.000	**2299.431**	**2310.000**	**776.374**	**100.000**	**169.431**	**169.525**	**Not Achieved**	**Design**
2145.000	**2314.915**	**2325.000**	**776.381**	**100.000**	**169.915**	**170.015**	**Not Achieved**	**Design**
2160.000	**2330.293**	**2340.000**	**776.389**	**100.000**	**170.293**	**170.394**	**Not Achieved**	**Design**
2175.000	**2345.593**	**2355.000**	**776.397**	**100.000**	**170.593**	**170.689**	**Not Achieved**	**Design**
2190.000	**2360.815**	**2370.000**	**776.405**	**100.000**	**170.815**	**170.898**	**Not Achieved**	**Design**
2205.000	2385.000	2385.000	776.367	100.000	180.000	180.064	Achieved	None
2310.000	2490.000	2490.000	776.435	100.000	180.000	180.000	Achieved	None
2325.000	**2495.268**	**2505.000**	**776.495**	**100.000**	**170.268**	**170.280**	**Not Achieved**	**Design**
2340.000	**2507.998**	**2520.000**	**776.516**	**100.000**	**167.998**	**168.055**	**Not Achieved**	**Design**
2355.000	**2520.134**	**2535.000**	**776.541**	**100.000**	**165.134**	**165.179**	**Not Achieved**	**Design**
2370.000	**2531.957**	**2550.000**	**776.568**	**100.000**	**161.957**	**161.924**	**Not Achieved**	**Design**
2385.000	**2548.636**	**2565.000**	**776.569**	**100.000**	**163.636**	**163.480**	**Not Achieved**	**Design**
2400.000	**2564.876**	**2580.000**	**776.572**	**100.000**	**164.876**	**164.541**	**Not Achieved**	**Design**
2415.000	**2580.776**	**2595.000**	**776.577**	**100.000**	**165.776**	**165.222**	**Not Achieved**	**Design**
2430.000	**2596.434**	**2610.000**	**776.584**	**100.000**	**166.434**	**165.637**	**Not Achieved**	**Design**
2445.000	**2611.921**	**2625.000**	**776.591**	**100.000**	**166.921**	**165.883**	**Not Achieved**	**Design**
2460.000	**2627.250**	**2640.000**	**776.599**	**100.000**	**167.250**	**166.004**	**Not Achieved**	**Design**
2475.000	**2642.437**	**2655.000**	**776.608**	**100.000**	**167.437**	**166.052**	**Not Achieved**	**Design**
2490.000	**2657.522**	**2670.000**	**776.617**	**100.000**	**167.522**	**166.115**	**Not Achieved**	**Design**
2505.000	**2672.526**	**2685.000**	**776.626**	**100.000**	**167.526**	**166.131**	**Not Achieved**	**Design**
2520.000	**2687.568**	**2700.000**	**776.636**	**100.000**	**167.568**	**166.174**	**Not Achieved**	**Design**
2535.000	**2702.554**	**2715.000**	**776.645**	**100.000**	**167.554**	**166.160**	**Not Achieved**	**Design**
2550.000	**2717.556**	**2730.000**	**776.655**	**100.000**	**167.556**	**166.162**	**Not Achieved**	**Design**
2565.000	**2732.567**	**2745.000**	**776.665**	**100.000**	**167.567**	**166.173**	**Not Achieved**	**Design**
2580.000	**2747.569**	**2760.000**	**776.674**	**100.000**	**167.569**	**166.176**	**Not Achieved**	**Design**

2595.000	**2762.423**	**2775.000**	**776.685**	**100.000**	**167.423**	**166.039**	**Not Achieved**	**Design**
2610.000	**2776.245**	**2790.000**	**776.700**	**100.000**	**166.245**	**164.978**	**Not Achieved**	**Design**
2625.000	**2789.774**	**2805.000**	**776.717**	**100.000**	**164.774**	**163.724**	**Not Achieved**	**Design**
2640.000	**2803.172**	**2820.000**	**776.735**	**100.000**	**163.172**	**162.380**	**Not Achieved**	**Design**
2655.000	**2817.617**	**2835.000**	**776.747**	**100.000**	**162.617**	**162.096**	**Not Achieved**	**Design**
2670.000	**2835.915**	**2850.000**	**776.739**	**100.000**	**165.915**	**165.649**	**Not Achieved**	**Design**
2685.000	**2852.891**	**2865.000**	**776.738**	**100.000**	**167.891**	**167.820**	**Not Achieved**	**Design**
2700.000	**2869.171**	**2880.000**	**776.741**	**100.000**	**169.171**	**169.236**	**Not Achieved**	**Design**
2715.000	**2885.013**	**2895.000**	**776.746**	**100.000**	**170.013**	**170.153**	**Not Achieved**	**Design**
2730.000	2910.000	2910.000	776.797	100.000	180.000	180.150	Achieved	None
3480.000	3660.000	3660.000	777.184	100.000	180.000	180.000	Achieved	None
3495.000	**3665.115**	**3675.000**	**777.246**	**100.000**	**170.115**	**170.134**	**Not Achieved**	**Design**
3510.000	**3677.608**	**3690.000**	**777.268**	**100.000**	**167.608**	**167.666**	**Not Achieved**	**Design**
3525.000	**3689.130**	**3705.000**	**777.296**	**100.000**	**164.130**	**164.161**	**Not Achieved**	**Design**
3540.000	**3702.644**	**3720.000**	**777.314**	**100.000**	**162.644**	**162.581**	**Not Achieved**	**Design**
3555.000	**3719.253**	**3735.000**	**777.315**	**100.000**	**164.253**	**164.036**	**Not Achieved**	**Design**
3570.000	**3735.472**	**3750.000**	**777.319**	**100.000**	**165.472**	**165.041**	**Not Achieved**	**Design**
3585.000	**3751.369**	**3765.000**	**777.324**	**100.000**	**166.369**	**165.678**	**Not Achieved**	**Design**
3600.000	**3767.048**	**3780.000**	**777.331**	**100.000**	**167.048**	**166.074**	**Not Achieved**	**Design**
3615.000	**3782.509**	**3795.000**	**777.338**	**100.000**	**167.509**	**166.254**	**Not Achieved**	**Design**
3630.000	**3797.600**	**3810.000**	**777.347**	**100.000**	**167.600**	**166.123**	**Not Achieved**	**Design**
3645.000	**3811.525**	**3825.000**	**777.362**	**100.000**	**166.525**	**165.046**	**Not Achieved**	**Design**
3660.000	**3825.119**	**3840.000**	**777.379**	**100.000**	**165.119**	**163.881**	**Not Achieved**	**Design**
3675.000	**3838.492**	**3855.000**	**777.396**	**100.000**	**163.492**	**162.565**	**Not Achieved**	**Design**
3690.000	**3851.931**	**3870.000**	**777.414**	**100.000**	**161.931**	**161.311**	**Not Achieved**	**Design**
3705.000	**3870.616**	**3885.000**	**777.404**	**100.000**	**165.616**	**165.292**	**Not Achieved**	**Design**
3720.000	**3887.757**	**3900.000**	**777.402**	**100.000**	**167.757**	**167.659**	**Not Achieved**	**Design**
3735.000	**3904.113**	**3915.000**	**777.404**	**100.000**	**169.113**	**169.170**	**Not Achieved**	**Design**
3750.000	**3920.007**	**3930.000**	**777.409**	**100.000**	**170.007**	**170.149**	**Not Achieved**	**Design**
3765.000	**3935.583**	**3945.000**	**777.416**	**100.000**	**170.583**	**170.743**	**Not Achieved**	**Design**
3780.000	3960.000	3960.000	777.377	100.000	180.000	180.122	Achieved	None

CONCLUSION

From the above results, it is clear that the M2 alignment with increased curve radius is most favorable in the area. The results from the above table show various results.

1. Table 4.16 clearly illustrates the decrease in the total length of the alignment up to 200-300 metes.
2. The fluctuating design speed of the existing alignment got stabled to 100 km/h with the elimination of the curves hence reducing the travel time.
3. The total cut and fill volume also got reduced. In existing alignment, the fill volume is greater than the cut volume that indicates the fill material had to be transported increasing the total cost of the structure. In both modified alignments the cut volume is greater than the fill volume hence no filling material is to be transported and the excess cut volume could be used as the pavement aggregate that would also result in cost minimization of the project.
4. The estimated cost of the modified alignment i.e. M1 is greater because of the higher cut volume on the other side the alignment M2 has less estimated cost due to the lower cut and fill volumes.
5. The actual cost of the road project is 26.64 CRS. and as per software calculations it cost comes out to be 26.27 CRS of alignment E1 which is close enough to the actual cost, hence the software precision is good.
6. The sight distance of the existing alignment is also poor. The curved sections of the existing alignment are not safe and need to be redesigned for a design speed of 100km/h.

From these results, we can see the errors in the existing alignment that could be minimized just by increasing the curve radius. If the curve radius could not be increased, then there should be road widening provided on the curves to make those curves safe. The road widening could also result in the increased overall cost of the alignment. The modified alignment M2 which has increased curve radius results in decreasing the cost of the existing alignment, and has a good sight distance, hence the modified alignment could be the most favorable for the area. It is also concluded that switching over to Openroads software, opens up more features in the designing of roads with good precision in all aspects.

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