Geometrical Design of Hilly Region Road Using Mx Road Software

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Abstract- *The environment and transportation are closely related and reliant on each other. In addition to promoting economic growth, sustainable transportation initiatives—like cleaner urban transportation systems and more effective rural road rehabilitation—also have significant social advantages. However, the environment and nearby communities may be significantly impacted by transport projects. The design of roadway alignments is typically predicated on minimising costs, including earthwork costs (cutting and filling). Road accidents and highway longevity are two examples of the issues that are taken into consideration when designing a decent and sustainable route alignment. These elements influence the creation of a sustainable road alignment.*

Roads built in a nation's mountainous areas are referred to as ghat roads or hillroads. In terms of alignment, design, building, and maintenance, these roads pose significant challenges. Hill roads are more prone to accidents due to their curves, sharp turns, steep grades, and narrow roadway width. Furthermore, a hill road's construction and upkeep are severely impacted by prolonged rain. Heavy rains can cause landslides and slips at numerous spots along the hill routes. Therefore, in order to build a sturdy and safe road, much attention must be taken throughout its layout and construction. Moreover, a large number of streams cross the road, and hence a suitable facility for cross drainage is needed. In this project, we are designing a hill road Gauharganj stretch through a distance of 6.1 km

Keywords: Geometric design, Hill roads, Cross sectional elements, Gradients Optimization Roadway Alignment and Mx road Software.

I. INTRODUCTION

In low- and middle-income nations, a dependable and secure transport system is essential to reducing poverty and promoting shared prosperity through sustainable economic growth. In order to create and preserve a good quality of life, road and highway systems play a crucial role. Since natural resources are limited, environmental conditions are delicate, and economic resources are scarce, many transportation planners, engineers, and environmental scientists around the world agree that roadway systems need to be more sustainable. Energy conservation and alternative energy generation are only two aspects of sustainability that affect the environment. Effective and successful project management requires the inseparable integration of environmental, community and society, and economic elements. A green or sustainable roadway cannot be achieved without taking into consideration environmental factors, including air quality, energy consumption, and terrain disturbance, even if the old roadway design process was primarily concerned with economic minimisation.

The design of roadway alignments is typically predicated on minimising short-term costs, like earthwork costs. On the other hand, designing the roadway alignment based on sustainability would be feasible if the design process adopted a long-term viewpoint that takes into account other significant factors, such as the total quantity of fuel consumption, time, and accident costs in the route's lifetime. A sustainable roadway design model that can assess and lessen the environmental impacts of roadways based on alignment geometries is the main goal of the current research study, which primarily aims to address roadway safety from a social, environmental, and financial perspective. Evaluation models are created for the following factors: economic, sight distance, and terrain disturbance to obtain a sustainable roadway alignment. These categories can be used to group the primary objections to roadway design:

- Social safety: The primary societal concerns influencing roadway design at various phases and through various approaches are safety-related. Roadway design can have a direct impact on safety, depending on the alignment of the vertical and horizontal axes.
- Economic: The economic factor, which determines the cost of road design, is the second consideration. Earthwork expenses, including filling and cutting, are the primary determining factors.
- Environmental: Environmental effects, such as changes to the landscape or its natural form and

quality following road project development, come in third.

The aforementioned factors were analysed using the MX road design software tool to calculate the necessary sight distance and cut and fill balance. A model comparing the sight distance needed for different alignments. Earthwork models are designed to reduce the overall volume of earthwork through filling and cutting. Each result has an equal volume, which balances the quantity of fill and cut volume. The planned alignment is reasonable in terms of earthwork costs, but it ignores environmental implications due to the terrain's natural shape. In this study, a novel approach was developed to reduce the amount of terrain disruption brought on by hauling. This technique reduces volume by adhering to the natural contours of the landscape rather than merely balancing the volume of cuts and fills.

OBJECTIVES OF THE RESEARCH

- To increase the design speed of the expressway to some extent.
- To modify the alignment or the other features where ever it is required.
- To investigate the significance of geometric alignment in road construction within hilly terrains.
- To provide recommendations for enhancing road safety, construction efficiency, and sustainability in hilly terrain through optimized alignment design.
- To compare the cost estimation of modified alignment with the actual cost of the project.
- Design curves in hilly areas to enhance safety considering a case study.

II. LITERATURE REVIEW

The research is a useful traffic accident modelling tool for determining the effects of highway geometric components and reducing accident rates based on road characteristics. Thus, a review of the literature was conducted in the areas of accident prediction and optimisation modelling, as well as accident causative variables, and the results are shown below.

REVIEW OF LITERATURE SUMMARY

Asha Davood Z et.al (2025) Considering the expansion of the current Kudappanamoodu-Vazhichal Junction road from 6 to 12 meters, the research's goal was to use Civil 3D to develop the new road's horizontal alignment and vertical profile.

With Civil 3D, the road's horizontal and vertical profiles can be designed with the least amount of time and effort. With high precision, Civil 3D can be utilised for road widening projects. The design specifics for enlarging the road from six meters to twelve meters were completed in this project. In alignment design, the balance line for cut and fill volume is an important component. The entire process of choosing the alignment must be redone if the cut and fill volumes are not equal. Since Civil 3D takes this requirement into account during the design process, it makes this part easier. Experts can complete the entire task in three working days, but a manual completion would take two to three months.

Ajay Kumar Gawande and Dr. Bablu Kirar (2024) intended to use civil 3D software to improve the horizontal and vertical geometry of the region surrounding Salkanpur Ghat in Madhya Pradesh, India, as well as the length from Bhopal to Salkanpur. Approximately 1.860 km of mountainous terrain make up this segment, which is dangerous due to its steep vertical slopes ranging from 6.5% to 7% and its hairpin turns. Due to these factors, the area is known to be prone to accidents, which can cause both financial and physical damage.

In comparison to the current route, the outputs show that both improved alignments are shorter, have smoother curves, and have lower maximum gradients (5.3% versus 7%). Further evidence of improved safety and efficiency for vehicular traffic comes from the substantial rise in the minimum design speed from 20 kmph to 65–80 kmph.

Ankit Choudhary et.al (2024) intended to create a collision prediction model that would enable the relevant authorities to pinpoint contributory factors that could have a major influence on crashes that happen on India's mountain roadways. The goal was accomplished by developing CPMs as a function of traffic factors, pavement surface quality, and road geometry. Developing safety performance functions (SPFs) for traffic crashes on rural roads in the mountainous Indian state of Uttarakhand was the main goal of this study.

The findings indicated that TSVC collisions are significantly impacted by the state of the pavement surface. The individual crashes 3.87 percent more frequently when rutting increases. Pavement markings also serve as a preventative strategy by lowering the likelihood of collisions. It is generally more perilous for both parties to collide on vertical curves. It is often observed that HC and VC cause 8.32% and 29.95% more TSVC crashes, respectively. In contrast, a little shift in accident frequency was noted for both vertical curves (10.96%) and horizontal curves (10.62%) in the case of TMVC. The frequency of crashes increased by 31% and 18% per unit drop in CW and SW, respectively, indicating that tapered carriage and shoulder width were crash-causing factors. When pavement markings are present, the number of TMVC and TSVC crashes is reduced by 49.5% and 26.9%, respectively. The TSVC model appears to offer superior goodness of fit and model complexity, according to the AIC and BIC values.

III. STEPS OF METHODOLOGY

Step 1- Topography Survey

Using Total Station survey equipment, the topographic survey has been conducted at the scene of accidents. Three-dimensional measurements of the current road are taken using a total station, a high-precision surveying tool. With the use of coordinate geometry and triangulation, this survey equipment can compute distance, angle, and coordinates in relation to a known place. Every measurement is managed by an internal program and interfaced through a computer. Surveying data has been visualised as vector entities by downloading the digitally acquired data into a CAD program (AutoCAD). Ultimately, this information was further examined using the design application software (MX Road), which is widely utilised in the design of highways.

Step 2- Topography Survey Methodology
Step 3- Traffic Study
Step 4: Data Import and Extraction
Step 5: Design Data
Step 6: Standard String Naming
Step 7: Surface Analysis
Step 8: Alignment Design
Step 9: Road Design
Step 10: Pavement design

In accordance with IRC regulations (IRC: 37-2018), the overall pavement thickness is determined experimentally using design tables and the CBR value of the subgrade soil to create the flexible pavement.

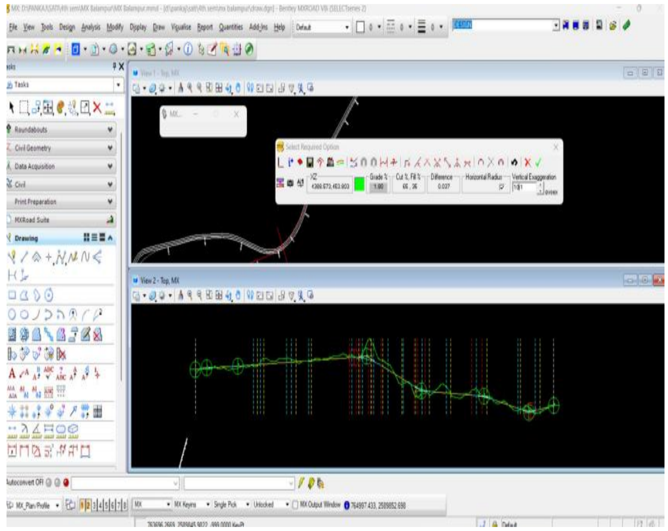

Fig 1: Vertical Profile

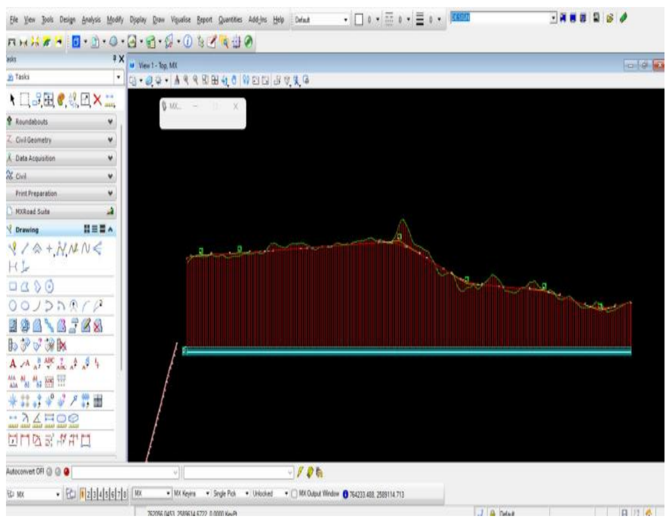

Fig 2: Output of Verticle Profile.

IV. RESULTS AND DISCUSSION

a) Horizontal Alignment

********Element A001 Straight********	
Bearing	154 25 50.329
Length	47.193
Begin on Straight Chainage	0+000.000
Begin on Straight X	384499.489
Begin on Straight Y	2035758.498
Straight End Chainage	0+047.193
Straight End Y	2035715.927
Straight End X	384519.858

*******Element A009 Arc********	
Intersection Point Chainage	0+070.204
Intersection Point X	384529.789
Intersection Point Y	2035695.17
Tangent	23.01
Arc Length	43.945
External	4.261
Middle Ordinate	3.979
Chord Bearing	133 26 54.343
Chord Length	42.969
Arc Start Chainage	0+047.193
Arc Start X	384519.858
Arc Start Y	2035715.927
Radius	60
Hand of Arc	Left
Arc End Chainage	0+091.138
Arc End X	384551.053
Arc End Y	2035686.377
Included Angle	415751.972
Arc Centre X	384573.982
Arc Centre Y	2035741.823

b) Vertical Alignment

********Element 1 Grade********	
Gradient	-1.371
Gradient Length	98.86
Begin on Gradient Chainage	0+00.00
Begin on Gradient Level	978.522
Gradient End Chainage	0+098.860
Gradient End Level	977.167

******Element2VerticalCurve******	
IP Chainage	0+320.875
IP Level	974.122
Middle Ordinate	-3.347
Algebraic Difference	-6.03
Curve Start Gradient	-1.371
Curve End Gradient	-7.401
Curve Length	444.031
Vertical Radius	-7364
M Value	-1.358
K Value	73.64
Curve Type	Hog
Sight Distance	179.944
Curve Start Chainage	0+098.860
Curve Start Level	977.167
Curve End Chainage	0+542.891
Curve End Level	957.69

Earth Work Quantity

Chainage	Volume Cut (m3)	Volume Fill (m3)
0	0	0
50	6509.766	0
100	6293.461	0
150	4008.511	0.05
200	997.778	780.948

Super Elevation Values

Reference String = MC00 Design Speed = 30 Slope/Gradient Units = Dec %

Table Curve Details

Section		ormal Crown Out: Outer Curve	ormal Crown Out: Inner Curve	ull Super Out	ull Super In	ormal Crown In: Inner Curve	ormal Crown In: Outer Curve
Chainage	Defined	27.138	03.138	9.138	9.193	5.193	1.193
Chainage	Rules	27.138	03.138	9.138	9.193	5.193	1.193
Left Slope	Defined	0.025	0.025	0.075	0.075	0.025	0.025

Left Slope	Rules	0.025	0.025	0.075	0.075	0.025	0.025
Right Slope	Defined	0.025	.025	.075	.075	.025	0.025
Right Slope	Rules	0.025	.025	.075	.075	.025	0.025
Length	Defined	8			8		
Length	Rules	8			8		
Grade	Defined	.0188			.0188		
Grade	Rules	.0188			.0188		
Radius				60	60		

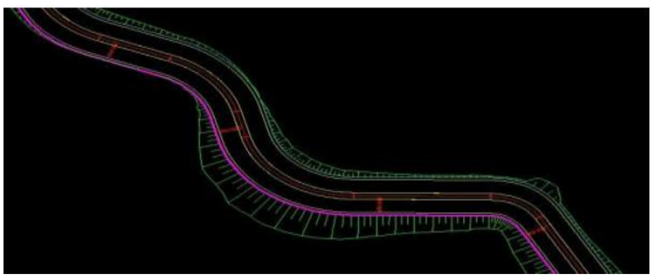

Fig 3: Horizontal Alignment Viewer

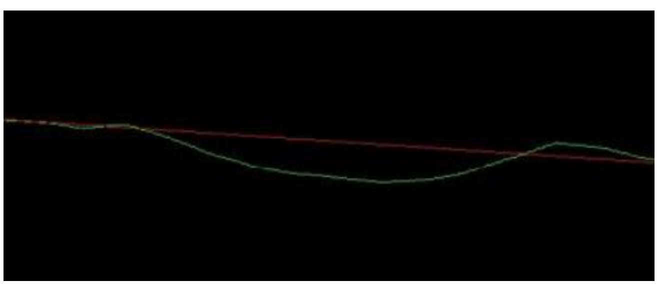

Fig 4: Vertical Alignment Viewer

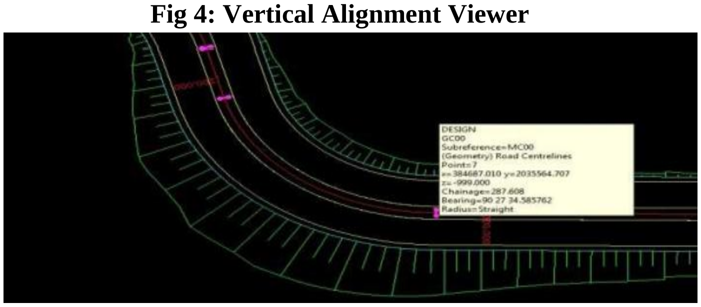

Fig 5: Alignment Showing Center Line String Details

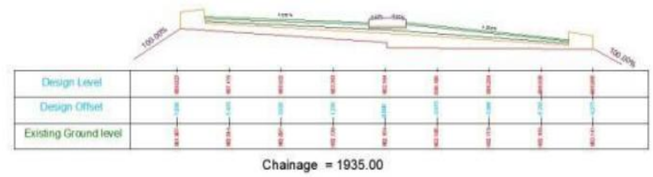

Fig 6: Cross Section

V. CONCLUSION

The geometric alignment of roads in hilly terrain represents one of the most complex challenges in transportation engineering due to steep gradients, sharp curves, unstable slopes, and environmental sensitivity. This thesis has explored the significance of geometric variables such as horizontal and vertical alignment, sight distance, superelevation, and cross-sectional elements, while emphasizing the critical role of advanced analytical tools like MX Road in optimizing road design. The findings reaffirm that traditional manual design methods often fall short in accommodating the intricate demands of hilly terrain, whereas MX Road provides a comprehensive solution through its parametric modeling, terrain integration, and 3D visualization capabilities. By enabling engineers to evaluate multiple alignment options, balance cut-and-fill quantities, and simulate road performance under real conditions, MX Road significantly enhances design efficiency, safety, and sustainability.

The study concludes that MX Road is not only a design software but also a decision-support platform that integrates technical standards with site-specific challenges, thereby reducing risks of accidents, landslides, and cost overruns in hilly road projects. However, the research also highlights certain limitations, such as dependency on accurate survey data, high training requirements for engineers, and constraints in integrating real-time traffic and geotechnical data.

- All the improvements are planned within the proposed right of way.
- The proposed alignment is designed to match with the existing alignment at major cross drainage sections.
- Design speeds are formulated for ruling Design Speed of 80 kmph and minimum design speed of 30 kmph.
- The proposed alignment encounters minimum horizontal curve radius at two minor junctions, where the speeds are restricted to minimum.
- Limiting gradient values are adopted for few sections where site restriction prevails. • The obtained base

traffic volume data has been projected to a period of 15 years (2014-2029).

- High design precision and saving in time were achieved by using MXROAD.
- The cost analysis indicates that preliminary activities such as scarification of the bituminous layer and preparation of the earthen sub-grade are priced modestly at ₹300 per unit area or volume. Sub-base and base layers show a significant cost rise, with the granular sub-base at ₹1650/m³ and wet mix macadam at ₹1935/m³, reflecting higher material and processing demands. Surface treatments, including the prime coat and tack coat, remain comparatively economical at ₹11/m² and ₹12/m², owing to their minimal application thickness. However, the bituminous layers exhibit notable cost variations: dense bituminous macadam is priced at ₹450/m², while bituminous concrete, being a superior surface layer with enhanced durability, is substantially higher at ₹11,500/m³, emphasizing its quality and performance role in pavement construction.

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