Geometric Design of a Highway using Mx Road

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Abstract - This study addresses the need for road widening to accommodate increasing traffic intensity on the Vijayawada Highway (30.8 km). Road widening can improve traffic performance by increasing capacity, though it may also attract more users. The research involves analyzing the effects of road widening on traffic flow and safety, using Bentley MX Road software for road geometric design. The project includes importing existing road geometry into the software, applying design standards, and generating alternatives for optimization. The redesign aims to improve efficiency, safety, and compliance with standards while minimizing costs and environmental impact.
Keywords: road widening, traffic performance, road capacity, geometric design, Bentley MX Road, Vijayawada Highway, safety, traffic flow.

1.Introduction

Roads are the primary mode of transportation in India, with a vast network extending over 5.89 million kilometers, making it the second-largest road network globally, just behind the United States with its 6.65 million kilometers. These roads are vital for the movement of people and goods across the country. India's national highways, connecting major cities, are classified based on the width of their carriageways. However, the country's main roads are currently under immense strain, requiring significant modernization to keep up with the growing demands of the economy.As traffic volumes in India continue to rise, maintaining existing roads and expanding them to accommodate more vehicles is essential. Widening roads to handle increased traffic flow will also facilitate higher average travel speeds. Therefore, it is critical to redesign the current road infrastructure to support the surge in vehicle movement efficiently. The expansion of road projects across India underscores the need for precise, efficient design methods to meet modern transportation demands. Another major concern is the increasing number of road accidents, often attributed to poor road design. In India, many accidents are caused by inadequate sight distance, particularly on curved roads. Designing curves with appropriate sight distances is both a challenging and time consuming task. For example, the Krishna district road stretch is surrounded by buildings, shops, offices, schools, and parks, with sharp curves that have very small radii—some as tight as 50 meters—forcing a significant reduction in design speed. Research by Jesna N.M. and M.V.L.R. Anjaneyulu on two-lane highways has shown that the safety of horizontal curves is primarily dependent on their radius. Their findings indicate that as the curve radius increases, so does the safety or reliability index. Larger curve radii allow for safer, smoother travel. To address these challenges, advanced road design software such as MX Road or Open Roads Designer by Bentley can be employed. These tools enable efficient and accurate road design, providing precision in calculations and saving valuable time. MX Road, for example, offers 3D visualization, giving designers a comprehensive view of the road layout, including earthwork and horizontal and vertical profiles. In this project, the road's horizontal and vertical alignments will be reconfigured to ensure adequate sight distances and increased curve radii, allowing vehicles to travel at higher speeds while maintaining safety.

2. Objectives

To maintain an effective radius for horizontal curves to ensure optimal vehicle placement and reduce accidents. • To review baseline maps of existing roads when designing new profiles, which helps in saving time and costs. • To provide safe sight distances and gradients to enable the highest possible speed safely. • To develop a design that is both safer and more cost-effective.

3.Scope of the present study:

Srikiran et al. (2018) conducted a geometric design study on a 10 km segment of NH-9, from Humnabad to Sangareddy, focusing on improving horizontal curves by increasing the radius of curvature to meet four-lane standards. They also optimized the vertical profile in line with sight distance, gradients, and economic considerations. This approach enabled the achievement of a design speed of 100 km/h for the stretch by enhancing the radius of the horizontal curves and optimizing the vertical curves.

Ali et al. (2018) worked on the design of a 1.51 km sub-arterial urban road, extending from Devegowda Circle to Nice Road via Kerekodi Road. The alignment featured a minimum horizontal curve radius of 40 meters, limiting the design speed to 30 km/h. Their design aimed for a ruling speed of 60 km/h, utilizing MX Road software for high precision and efficiency.

Srikanth and Raveesh (2019) designed a rigid pavement for a route from Thullar to Amravati in Andhra Pradesh, emphasizing the increase of horizontal curve radii to reduce highway accidents. They set a ruling design speed of 100 km/h, with a minimum of 30 km/h. The proposed alignment included areas with minimum curve radii at two minor junctions, necessitating speed reductions.
Akshay et al. (2018) conducted geometric design work for a section of NH 99, from Nawadih to Chandwa, prioritizing

safety and appropriate travel speeds. They enhanced both vertical and horizontal geometry to support a design speed of 100 km/h using MX Road software.

Kumar et al. (2015) focused on the geometric design of SH-131 to upgrade the existing roadway with improved geometric features through MX Road software. Meanwhile, Malooa et al. (2016) standardized baseline surveys for the road sector in Chikurde and Bhulane, Maharashtra, creating a flexible framework for village road design.
Das et al. (2016) noted that vehicles tend to gravitate towards the road center on curves, with a more pronounced shift as the curve radius increases. Nazimuddin et al. (2017) designed alignments to match existing layouts at major drainage sections, incorporating a ruling speed of 100 km/h and adhering to gradient limitations.
Horníček and Rakowski (2017) developed a crack propagation barrier method combining geogrids and various material layers to minimize reflective cracking during road reconstruction. Kozlov et al. (2017) highlighted a shift in Russia towards user-friendly infrared toll stations.
Yao et al. (2019) found that foundation settlement increases with higher surcharge loads, while longer column lengths mitigate this effect. Kefei et al. (2016) focused on measuring surface characteristics of warm mix asphalt using an Atomic Force Microscope.
Hossain et al. (2019) revealed that axle load peak values for Class 9 vehicles were higher than default values. Dive et al. (2016) reported that increasing base layer thickness reduces rutting damage but less so for fatigue damage. Sabih et al. (2018) concluded that concrete strength improves with higher elastic modulus, affecting performance. Martin et al. (2016) noted rapid pavement deterioration following flooding. Chen et al. (2016) introduced a cyclic fuzzy set model for material analysis. Luo et al. (2016) derived equations for beam deformation in concrete pavements, and Svatovskaya et al. (2017) explored soil strengthening techniques. Grygierek et al. (2017) continued research on geogrids and stiffness, while Peng and Zornberg (2017) effectively used transparent soil for displacement analysis.

4.Materials and Methodology

The methodology commenced with a comprehensive review of existing research on highway design and software applications in India. This initial phase aimed to identify key issues affecting highway design. Based on the insights gained from the literature review, effective solutions were developed.

Data collection for the new design focused primarily on highway widening and increasing curve radii. After gathering the necessary information, appropriate design parameters were selected to guide the project. A new centerline was then established, serving as the foundation for subsequent design activities.

Following this, the team formulated the horizontal and vertical alignments, taking into account necessary factors such as superelevation and cross-sections. Earthwork, pavement, and sub-grade designs were also developed as part of the design process.

Ultimately, the methodology culminated in a final cost estimation for the project, ensuring that all aspects of the design were thoroughly evaluated and accounted for. This structured approach allowed for a comprehensive design that addressed the identified issues while adhering to the necessary standards and requirements for highway construction. As shown in flow chat fig.1.

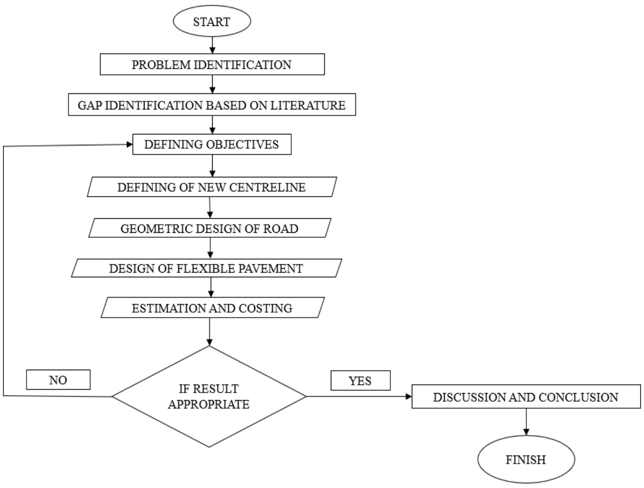


Fig.1 Methodology flowchart

4.1 MX Road software

MX Road, developed by Bentley Systems, a UK-based company, has seen numerous upgrades to adapt to the increasing demands for accuracy and efficiency in highway design. This advanced string-based modeling tool enables rapid and precise design of various road types. With MX Road, highway designers can efficiently finalize design alternatives and automate many detailing processes, leading to significant time and cost savings.

The software employs 3D string modeling technology, a robust yet user-friendly approach for creating 3D surfaces. Its interoperable database allows engineers to create and annotate 3D project models compatible with popular AEC platforms and Windows.

Recently, highway projects in India have increasingly relied on Public-Private Partnerships, reflecting a shift toward collaborative approaches in infrastructure development. MX Road's capabilities support these initiatives by streamlining the design process, ensuring that projects meet the necessary standards while facilitating efficient collaboration among stakeholders. This combination of advanced technology and collaborative frameworks positions MX Road as a vital tool in the evolving landscape of highway design.

4.2 Applications of the software

MX Road delivers high precision in road construction within constrained land widths, helping to reduce land acquisition costs, which directly impact the overall project budget. It facilitates the alignment of horizontal designs for upgrade projects to integrate seamlessly with existing cross-drainage structures and adjusts vertical profiles to align with current levels of these structures. The software effectively designs various geometric elements, such as carriageways and shoulders, and allows for precise control of design parameters including design speed, horizontal curvature, superelevation, and vertical curvature.

4.3 COMPONENTSOF FLEXIBLE PAVEMENT

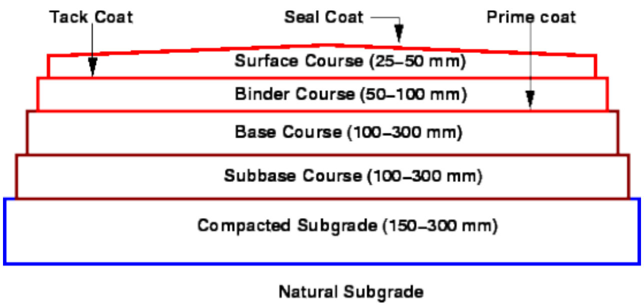


Fig.2 Cross-section of a flexible pavement

4.4 SOILSUBGRADE

The soil subgrade, composed of natural or selected soil compacted in layers, serves as the lowest layer of the pavement system, supporting all other layers and traffic loads. In India, the minimum thickness is 500 mm for National and State Highways and major arterial roads, and 300 mm for rural roads. Proper drainage is vital for maintaining soil strength and support year-round.

4.5 GRANULARSUB-BASE ANDDRAINAGE LAYER

The Granular Sub-Base (GSB) course functions as an effective drainage layer within pavements and must endure lower compressive stresses compared to the base course. Consequently, aggregates with lower strength but good permeability can be used in the GSB layer. Crushed stone aggregates are commonly employed in GSB layers for major highways due to their high permeability, which enhances drainage. Coarse-graded aggregates with a low percentage of fines (less than 5% finer than 0.075 mm) are ideal for ensuring effective drainage

4.6 GRANULAR SUBBASE-AND DRAINGANGE LAYER

The granular base course is a crucial component of flexible pavements, designed to absorb wheel load stresses and distribute them over a larger area onto the Granular Sub-Base (GSB) layer beneath. A high-quality base course significantly improves the load-carrying capacity of the flexible pavement structure. Typically, good quality coarse aggregates are used for the granular base course. According to the specifications set by the Ministry of Road Transport and Highways (MoRTH), Government of India, the aggregates for the base course should have a low Aggregate Impact value (less than 30%) and a low Los Angeles Abrasion value (less than 40%).

4.7 Thin bituminous surface

The thin bituminous surface course acts as a barrier to prevent surface water from infiltrating the pavement layers during rain, thereby protecting the base course and other underlying layers. A well-maintained surfacing combined with an effective drainage layer helps keep the soil subgrade relatively dry, preserving its stability. Additionally, the bituminous surfacing functions as a wearing course for traffic, providing a dust-free pavement surface in dry conditions.

4.8 Detail sof project area

A case study is conducted on a state highway, specifically the Jhalawar-Payli road, as illustrated in the figure. Jhalawar, a city in the southeastern part of Rajasthan, India, is situated at an average elevation of 312 meters (1023 feet). The existing 2-lane road, with a width of 7 meters, has been redesigned with an increased curve radius to enhance safety. In order to carry out this research a different method is used for both Geometric and PavementDesignofhighwaybyuseofMXRoadsoftware.Theg roundprofileoftheexisting2laneroadfrom Jhalawar to Payli was given using which the new 2 lane road is to be designed for the given stretch. As shown in fig.3.

Fig 2 : Locating study area from Google Earth

5. DESIGN OF FLEXIBLE PAVEMENT

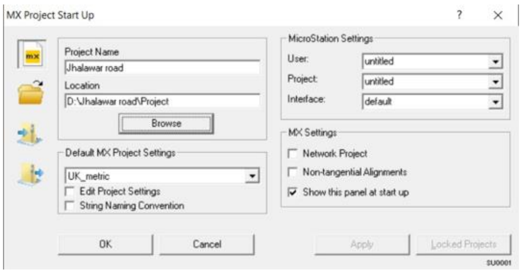
IRC: 37- 2018 pavement method require a large number of below listed parameters to be evaluated and used for the design of flexible pavement as presented in Table 1

Traffic input parameters for flexible pavement design as per IRC:37-2018
Base year traffic volumes of commercial vehicles in terms of AADT
Design period
Traffic growth rate
Composition of commercial traffic in terms of single, tandem, tridem and multi-axles
Vehicle damage factors
Lane distribution factors

Table 1. Design of flexible pavement

5.1 Base year traffic volumes

A comprehensive survey of the project road was conducted in May 2018, referred to as the "Base Year." Traffic projections and growth rates for various vehicle types, detailed in a separate Traffic Study Report, have been analyzed. For pavement design, commercial vehicles with a



gross vehicle weight exceeding 3 tons—including buses, light goods vehicles (LGVs), 2-axle trucks, 3-axle trucks, and multi-axle trucks—have been considered. Based on traffic characteristics, the project road has been segmented into two homogeneous sections according to traffic estimates, as outlined in Table 3.7.2.

Table 2. Traffic homogeneous sections

Homogeneous Section (HS)	Existing Chainage (km)		Length(km)
	From	To	
HS-I	106+000	110+000	4.00
HS-II	110+000	129+050	19.05

5.2 Design life

The design life represents the anticipated duration of the pavement, from construction until it requires reconstruction. Pavements are generally designed to accommodate the expected traffic throughout this period. For flexible pavements, a design life of 15 years is standard, while for rigid pavements, it is 30 years. These design lifespans adhere to IRC guidelines.

5.3 Taffic growth rates

Traffic growth rates have been considered for each category of vehicles using econometric models. A minimum traffic growth rateof5%, incompliance with IRC: SP:073-2007(Clause5.5.4) is considered for design

6. Results and Discussion

To develop the new data alignment, various design steps were followed according to industry standards using specialized software. Based on the analysis results, the data was reorganized and optimized, followed by thorough discussions. The new data alignment was then compared to the standard approach in terms of efficiency, accuracy, and overall cost-effectiveness. The following are the design steps taken for the new data structure.

6.1 Plotting of data in open roads

Importing necessary data

- Rename the data file as 'spot.csv'.
- Create a folder on the drive named 'Jhalawar Data' and include two subfolders within it named 'Raw Data' and 'Processed Data'.
- Copy the 'spot.csv' file into both the 'Raw Data' and 'Processed Data' folders.
- When opening the data processing software, a dialogue box will appear; click on 'Create New Project'. Name the project 'Jhalawar Data' and click on 'Browse'.

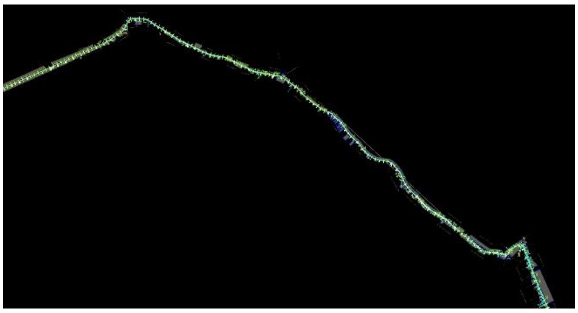
In the browse tab, navigate to D:/Jhalawar Data/Processed Data and click 'OK'. As shown in figure.

Fig 5. Creating new project

Fig.6. Existing road profile

Creating new model

- In the data conversion tool, create a model named 'DATASET'.
- Within the 'DATASET' model, define all relevant parameters such as Categories, Fields, Data Types,



and Labels based on the requirements for the new data structure.
- Next, navigate to Display > Clear Display…, and then Display > View with Style Set…, select the 'DATASET' model and click OK.
- A new window will open, displaying the selected parameters from the existing data profile.

6.2 Analysis of horizontal alignment

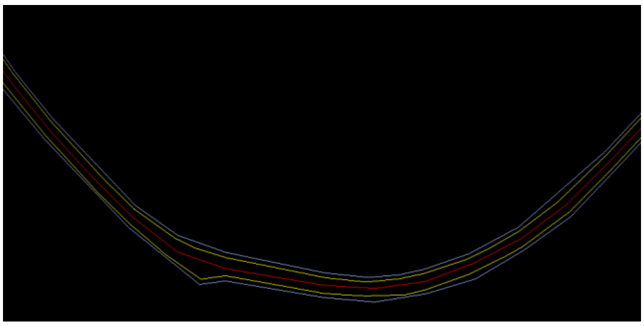


Fig.6 GROUND model displaying the selected parameters for new design

ow go to Design> Quick Alignment> Horizontal Design…, in the displayed tab create a new model 'DESIGN' and name string as 'MC00' and click Next.

7.Conclusion

MX Road is a string-based road design software developed by Bentley Systems, recently upgraded for faster and more accurate results. Creating a new data alignment in accordance with the existing data profile is straightforward using this software. Additionally, horizontal and vertical data profiles can be easily defined. Similarly, tasks such as data adjustments, cross-sections, data analysis, field definitions, and structural design were efficiently managed using the software.

Compared to conventional methods, software tools have significantly saved time and resources. Using MX Road software, the time required to design a road and estimate volumes and construction costs is greatly reduced. In this project, the primary focus was on reducing costs and enhancing road safety. This was achieved by redesigning the alignment of the existing road and decreasing the overall length by increasing the radius of curves. As a result, the distance and the number of curves were reduced, shortening the travel time between Jhalawar and Payli. The new design was then compared to the previous one to calculate changes in volume and cost reduction, summarized below.

From the above earthworks report it can be concluded that:
Reduction in volume cut and fill= (4688.432 – 4444.956) + (49886.17 – 47305.95) = 243.476
+ 2580.22= 2823.696 m^3
Therefore, cost reduced in volume cut and fill= 3960875.1 – 3755912.1= Rs 204963
From the above pavement layers report it can be concluded that:
Reduction in volumes of different layers:
BC= 4758.52 – 4352.6= 405.92 m^3
DBM= 7340.16 – 7000= 340.16 m^3
WMM= 31246.8 – 30021.46= 1225.33 m^3
GSB= 16967.45 – 16051.96= 915.48 m^3
Therefore, cost reduced in pavement= 67035155.94 – 63111118.68= Rs 3924037.26
Table 7. Drain down by wire basket method

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