Standards of Geometric Design of Highway: A Review

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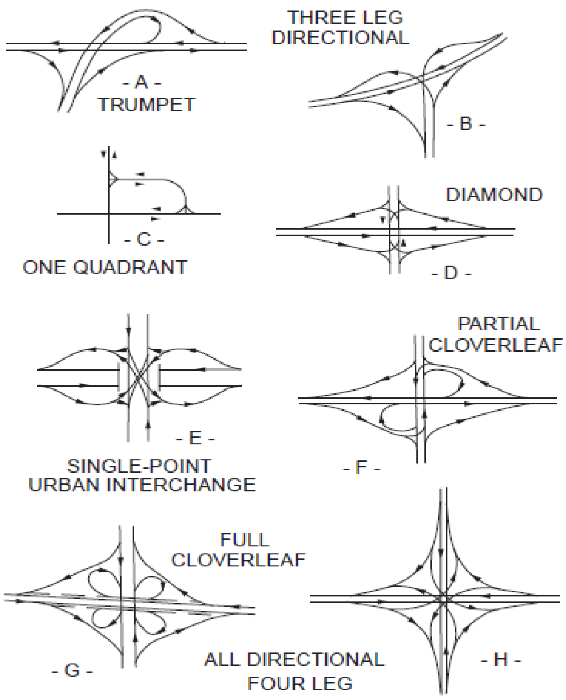
Abstract: *Geometric design of highway deals with designing of physical visible features of highway those comprise of cross-sectional elements, sight distances, alignment, curves, superelevation, and other allied features. India is one of the country having population increases progressively causes traffic volume more. In addition to that sanctioning of funds from government for transportation infrastructure development is not satisfactory. So that it is preferable to plan and design the geometric elements of the road during the initial alignment stage it by considering future traffic growth. And it is very difficult to improve geometric elements after construction and cause to unwanted capital investment. This paper presents review on past work done on geometric design of highway and emphasize planning and designing of geometric features. Although there are number of factors influences on design of highway, but suitable geometric design having objective of giving optimum efficiency in traffic operation with contentment safety measures at reasonable cost.*

Keywords: Geometric Design, Super Elevation, Cross Sectional Elements, Optimum Efficiency.

INTRODUCTION:

Geometric design of highways refers to the design of the visible dimensions of such features as horizontal and vertical alignments, cross sections, intersections, and bicycle and pedestrian facilities. The main objective of geometric design is to produce a highway with safe, efficient, and economic traffic operations while maintaining esthetic and environmental quality. Geometric design is influenced by the vehicle, driver, and traffic characteristics. The temporal changes of these characteristics make geometric design a dynamic field where design guidelines are periodically updated to provide more satisfactory design. AASHTO design a Policy on Geometric Design of Highways and Streets which is based on many years of experience and research. Repeated citation to AASHTO throughout this chapter refers to this policy. This paper discusses the fundamentals of highway geometric design and their applications and is divided into four main sections: fundamentals of geometric design, basic design applications, special design applications, and emerging design concepts. It draws information mostly from the AASHTO policy and TAC guide and provides supplementary information on more recent developments. Since geometric design is a major component in both the preliminary location study and the final design of a proposed highway, it is useful to describe first the highway design process. The design process of a proposed highway involves preliminary location study, environmental impact evaluation, and final design. This process normally relies on a team of professionals, including engineers, planners, economists, sociologists, ecologists, and lawyers. Such a team may have responsibility for addressing social, environmental, land-use, and community issues associated with highway development. The preliminary location study involves collecting and analyzing data, locating feasible routes, determining preliminary horizontal and vertical alignments for each, and evaluating alternative routes to select the best route. The types of data required are related to the engineering, social and demographic, environmental, and economic characteristics of the area. Examples of such data are topography, land use pattern, wildlife types, and unit costs of construction. A preliminary study report is prepared and typically includes a general description of the proposed highway, a description of alternative locations and designs, projected traffic volumes and estimated total costs, an economic and environmental evaluation, and a recommended highway location. Before the project is approved, it is common to hold public hearings to discuss the preliminary study and environmental impacts. Highway construction may impact the environment in a number of areas, including air quality, water quality, noise, wildlife, and socioeconomics. For example, highways may cause loss or degradation of a unique wildlife habitat and changes to migratory patterns. Socioeconomic impacts include displacement of people and businesses, removal of historically significant sites, and severance of the interpersonal ties of displaced residents to their former community. It is therefore essential that environmental impacts of alternative highway locations be fully evaluated. Provisions of the National Environment Policy Act of 1969 require that an environmental impact statement (EIS) be submitted for any project affecting the quality of the environment. The EIS must describe the environmental impacts of the proposed action, both positive and negative probable unavoidable adverse environmental impacts; secondary environmental impacts such as changes in the pattern of social and economic activities; analysis of short- and long-term impacts; irreversible and irretrievable commitments of resources; and public and minority involvement.



Interchange Configurations of Geometric Design of Highways

Interchanges provide the greatest traffic safety and capacity. The basic types of interchanges are shown in the trumpet pattern provides a loop ramp for accommodating the lesser left turn volume. The three leg directional pattern is justified when all turning movements are large. The one quadrant interchange is provided because of topography, even though the volumes are low and do not justify the structure. Simple diamond interchanges are most common for major–minor highway intersections with limited right of way. A full cloverleaf interchange is adaptable to rural areas where the right-of-way is not prohibitive, while a partial-cloverleaf interchange is normally dictated by site conditions and low turning volumes. An all direction four leg interchange is most common in urban areas where turning volumes are high. High-occupancy vehicle (HOV) roadways, designated for buses and carpools (typically with three or more persons per vehicle), have been incorporated into urban freeway corridors to improve traffic operations. There are three basic types of HOV lanes. The concurrent flow type provides an HOV lane normally on the left lane of the roadway in both directions. The HOV lane is separated from the regular use lanes with a buffer. The contra-flow type designates an HOV lane in the opposing direction of travel. Geometric design of highway deals with designing of physical visible features of highway those comprise of cross-sectional elements, sight distances, alignment, curves, super elevation, and other allied features. Here is a brief definition of some geometric elements.

Alignment: The alignment is the route of the road, defined as a series of horizontal tangents and curves.

Profile: The profile is the vertical aspect of the road, including crest and sag curves, and the straight grade lines connecting them.

Cross Section: The cross section shows the position and number of vehicle and bicycle lanes and sidewalks, along with their cross slope or banking. Cross sections also show drainage features, pavement structure and other items outside the category of geometric design.

Sight Distance: Road geometry affects the sight distance available to the driver. Sight distance, in the context of road design, is defined as "the length of roadway ahead visible to the driver.

Cross Slope: Cross slope describes the slope of a roadway perpendicular to the centre line. If a road were completely level, water would drain off it.

Crest Curves: Crest vertical curves are curves which, when viewed from the side, are convex upwards. This includes vertical curves at hill crests, but it also includes locations where an uphill grade becomes less steep, or a downhill grade becomes steeper.

Superelevation: To counter-act the effect of centrifugal force and reduce the tendency of vehicle to overturn and to skid laterally outwards, pavement outer edge is raised with respect to inner edge. Thus, providing a transverse slope is known as Super elevation.

Horizontal Curves: Horizontal curves are provided to change the direction of centre line of the road. When a vehicle negotiates a horizontal curve, centrifugal force acts outwards through centre of gravity of the vehicle which depends upon the radius of curve and speed of vehicle.

Transition curve: To enable gradual introduction of superelevation and the centrifugal force on a vehicle negotiating a horizontal curve avoiding sudden jerk on the vehicle, a transition curve is introduced whose radius reduces from infinity at tangent point to a designed radius of the circular curve

REVIEW OF LITERATURE:

He had stated that shoulder wider than 2.25m give additional safety. Average single vehicle accident rate for highway curves is about four times the Average single vehicle accident rate for highway tangents. Horizontal curves are more dangerous when combined with gradients and surfaces with low coefficient of friction. There is only a minor decrease in the speed adopted by drivers approaching curves of radii which are significantly less than the minimum radii specified for the design speed. Horizontal curves are more dangerous when combined with gradients and surfaces with low coefficient of friction. Horizontal curves have higher crash rates than straight sections of similar length and traffic composition. The difference becomes apparent at radii less than 1000m. The increase in crash rates becomes particularly significant at radii below 200m. small radius curves result in much shorter curve lengths and overall implications for crashes may not be as severe as would first appear. They were presented formulas in pavement widening on horizontal curves. To prevent off tracking, extra widening of pavement is provided at horizontal curves which is called mechanical widening.

$$Wm = nl^2/2R$$

W_m is mechanical widening

"R" is mean radius of curve

"n" is number of lanes

"l" is length of wheel base

$$W_{ps} = v/(2.64\sqrt{R})$$

"v" is design speed in metre per second

A fuel consumption model is developed based on highway geometric characteristics like grades, length and location of crest & vertical curves, speed & road surface type & condition. The output of fuel consumption model is the amount of fuel consumed by the vehicle while it travels along a highway at cruising speed.

Fuel consumption model limitations:

- It is only for passenger car units. It will be update with consideration of other type of vehicles.
- It is does not yet consider the effect of intersections& junction points with existing roads.
- It is not suitable for vehicle travelling along highway curved sections where acceleration and deceleration are needed due to variety design speeds.

He includes geometric factors of road and data collection and analysis of geometric parameters. The aim of this study is to find the role of the geometric factors of road on accident rate in the case of plain terrain and also find the extent to which these factors affect the accident rate for rural areas. The study aims to find the impact of factors like extra widening, horizontal radius, sight distance, K-value, super elevation, horizontal arc length, vertical arc length, vertical gradient on the accident rate and aims to study the significant factors causing accidents and to find the values for future design of roads. This policy states standards for highway designing elements. It states design standards for different road classifications, traffic volume and capacity, design speed, and sight distances along with design procedure. It gives specifications of highway geometric elements, terrain classification, and design speed for different types of highways and design traffic and capacity. It gives basic methodology involved the development of cross sectional models. For each State, individual models predicting crash rate per kilometer for typical sections of two-lane, four-lane undivided, and four-lane divided (non-freeway) roadways were developed. Over-dispersed Poisson models were fitted to the data. Crash rate per kilometer differences between pairs of road classes were then calculated as a measure of safety effect. They used negative binomial regression analysis to estimate the effect of cross-section design elements on total fatality and injury crash rates for various types of rural and urban highways at different traffic levels. The results show that depending on the highway type investigated increasing lane width, median width, inside shoulder width, are effective in reducing crashes. They got three approaches to relate accident rate to geometric characteristics and traffic related explanatory variables: Multiple Linear regression, Poisson regression and Negative Binomial regression. Various models have been intensively tested and validated. The adjustment of the models is based on historical accident data and on the characteristics of experimental sections selected from the road network. For example, Multiple linear and Poisson regression were used. In order to estimate accident rates using traffic and geometric independent variables. Moreover, he developed a model to identify the most significant traffic and geometric elements in predicting accident frequency. They used both the Poisson and negative binomial regression models. It should be pointed that, in using such models for future forecast one has to be careful as this entails extrapolating outside the range where the real observations were made. These models can be used for short-term forecast of 1–3 years. It is advisable that whenever data is available, these models should be updated through recalibration. They focused on relationship between rural road geometric characteristics, accident rates and their prediction, using a rigorous non-parametric statistical methodology known as hierarchical tree-based regression. Their goal is twofold; first, it develops a methodology that quantitatively assesses the effects of various highway geometric characteristics on accident rates and second, it provides a straightforward, yet fundamentally and mathematically sound way of predicting accident rates on rural roads. The results show that although the importance of isolated variables differs between two-lane and multilane roads, 'geometric design' variables and 'pavement condition' variables are the two most important factors affecting accident rates. He had studied safety factors on horizontal curves of two lane highways and added that Horizontal curves have higher crash rates than straight sections of similar length and traffic composition; this difference becomes apparent at radii less than 1000 m. The increase in crash rates becomes particularly significant at radii below 200 m. Roadway and geometric features that influence safety at horizontal curve sections are:

- ✓ Traffic volume on the curve and traffic mix (such as the percentage of trucks)
- ✓ Curve features (such as degree of curve, curve length, superelevation, presence of transition curves)

- ✓ Cross sectional curve element (such as lane-width, shoulder width, shoulder type, shoulder slope)
- ✓ Curve section roadside hazard features (such as clear slope, rigidity, and types of obstacles)
- ✓ Stopping sight distance on curve (or at curve approach)
- ✓ Vertical alignment on horizontal curve
- ✓ Distance to adjacent curves
- ✓ Distance of curve to nearest intersection, driveway, etc.
- ✓ Pavement friction

They develop Accident Modification Factors (AMFs) for median characteristics on urban and rural freeways and on rural multilane highways. A series of negative binomial regression models was used to determine the effects of independent variables on crashes. Variables considered in developing the base models included average daily traffic, left-shoulder width, barrier offset, median (with shoulder) width, and pole density. This approach for AMF development assumes that first each AMF is independent because the model parameters are assumed to be independent, and second the change in crash frequency is exponential. AMF equations were developed for urban and rural medians with rigid barriers, urban medians without barriers, and rural medians without barriers. They stated that Highway alignment optimization based on cost minimization requires comprehensive formulation of costs sensitive to alignment and development of efficient solution algorithms. In order to solve real-world problems, the optimization algorithms should work directly with a Geographic Information System (GIS) which stores relevant geographic information, such as land boundaries, environmentally sensitive regions, and topographic data and presented a model for highway alignment optimization that integrates a GIS with genetic algorithms, examines the effects of various costs on alignment selection, and explores optimization in constrained spaces that realistically reflect the limits on road improvement projects.

CONCLUSION:

The fundamentals of highway geometric design and their applications are presented in this paper. They include highway type, design controls, sight distance, and simple highway curves that influence the design of four basic highway elements: horizontal alignments, vertical alignments, cross sections, and intersections. Recent information on the design of complex highway curves, three-dimensional alignment design, sight distance needs for trucks, design considerations for RRR projects, and economic evaluation is presented. Emerging design concepts, including design consistency, design flexibility, safety audits, human perception, and smart design, are described. Geometric design guidelines promote safety, efficiency, and comfort for the road users. However, strict application of these guidelines will not guarantee obtaining a good design. The following key ingredients are also required:

- **Consistency:** Geometric design should provide positive guidance to the drivers to achieve safety and efficiency and should avoid abrupt changes in guidelines. Highways must be designed to conform to driver expectations.

- **Esthetics:** Visual quality can be achieved by careful attention to coordinating horizontal and vertical alignments and to landscape developments. The process can be greatly aided by using computer perspectives and physical models.
- **Engineering Judgment**: Experience and skills of the designer are important in producing a good design. Considerable creativity is required in developing a design that addresses environmental and economic concerns.

Future research in geometric design will likely involve a number of areas, such as human factors, smart technologies, design consistency, design flexibility, and reliability analysis. In particular, the link between geometric design and human factors (which contribute to 90% of road collisions) will require a significant research effort to improve our understanding of the lose link between how roads are built and how people use them. The dynamic nature of geometric design will aid these developments.

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