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Case Study on the Effect of Geometric Design Consistency on Level of Safety for Rural Roads under Indian Conditions

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Abstract - *Most dominant modes of transportation which we use today includes road, rail, water, and air transport. Each category of mode has its own infrastructure, vehicles, and operations, and often has unique regulations. In developing country like India most of traffic usually uses this mode of transportation. Being very flexible in nature and facilitating the easy movements, this mode is considered as priority for most of the road users, which in turn increases the road traffic. This increasing vehicular traffic also increase the number of accidents which requires attention and intervention at the early stage. Based on the previous studies it was found that accidents may occur due to many possible reasons, therefore, these reasons/issues should be accounted in the design & developing stage and the same shall be considered during implementation. Hence this directs the transportation engineers to compulsorily develop safer roads. The study also focuses on the same by giving a relative ranking to the road based on the Potential Safety Improvement Index (PFI). The study also uses many road safety audit (RSA) principles in assessing the road design. This research would help researchers in finding accidental prone areas or the areas where accidents are likely to happen due to poor geometric design. Study focuses on identifying the design issues in geometry of road. The main aim of this study is to analyze and give scope of the reduction of accidents and providing safe and forgiving roads by improving the inconsistency in the geometrics of the road.*

Key Words: **Road Safety, Level of Safety, Safety Index, Road Safety Audit, Blackspots.**

1. INTRODUCTION

Geometric design mainly deals with the dimensions and the of visible features of the road. It should be designed in such a way to provide optimum efficiency in traffic operations with achieving maximum safety at reasonable cost. It could be possible to design and construct the roads at any point of time based on the requirements or when the road gets deteriorate but it is rather expensive and difficult to improve the geometry at later date. Therefore, it is important to plan and design the geometric features during the initial alignment itself taking into consider the future growth and cost to be incurred in case of accidents for a given road. These issues can be identified by a formal process of Road Safety Audit (RSA) which helps in improving the operationality of the road and hence increasing the level of safety of the road.

1.1 Road Safety Audit

Road safety plays a vital role in defining the safety performance or examination of an existing or future road or intersection by an independent or a multidisciplinary team. Road safety audit in the research will help to qualitatively estimate the potential road safety issues and to report them to identify the opportunities for improvements in safety for all road users.

1.2 Details of Highway Geometrics

Most of the accidents which occur on the highways may be due to the deficiency in the highway alignment, this alignment is governed by two categories Horizontal Alignment and Vertical Alignment.

Horizontal Alignment: Horizontal alignment includes the design of horizontal curves, super elevation, transition lengths, deflection angle, speed, extra widening. A horizontal highway curve is a plan to provide a change in direction in the center line along the highway. When a vehicle goes along a horizontal curve, a force called as centrifugal force acts horizontally outwards throughout the center of gravity of the vehicle. More the horizontal curve lesser will be the chances of accidents. Accidents on horizontal curves could be due the two reasons: 'Running off the road and hitting an object' and 'Lost control and Rolled over. The apparent cause of these accidents is usually the driver entering the bend at too high a speed or he may be misjudged the severity of the bend. Such misjudgements can be caused because of the bend's visual configuration, poor delineation or because it was unexpectedly sharp after a series of gentle curves or after a long straight (tangent) section. On gravel roads, the loss of super-elevation in the cross-sectional profile through lack of maintenance may result in the effects of a horizontal curve being more severe than as designed. Super elevation is the rotation of the pavement to counteracting centrifugal force which prevents vehicle going off the road by moving across the curve. The criteria for the use of maximum and minimum super elevation rates may vary based on several variables, such as terrain, weather, highway location (urban vs. rural).

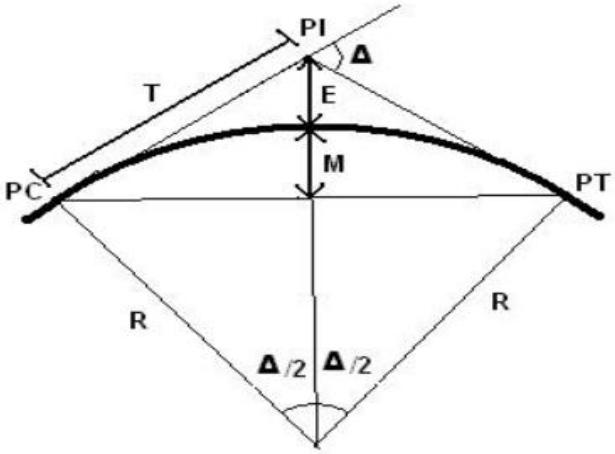

Fig -1: Sample representation of Horizontal curve

Vertical Alignment: Vertical alignment includes the design of vertical curves, sight distance, up or down gradients. Vertical curve is a parabolic curve that is applied to make a smooth and safe transition between two grades on a roadway or a highway. Vertical alignment governs the design of profile is the vertical aspect of the road, including combinations of crest and sag curves, and the straight grade lines (created on both down and up grades) connecting them.

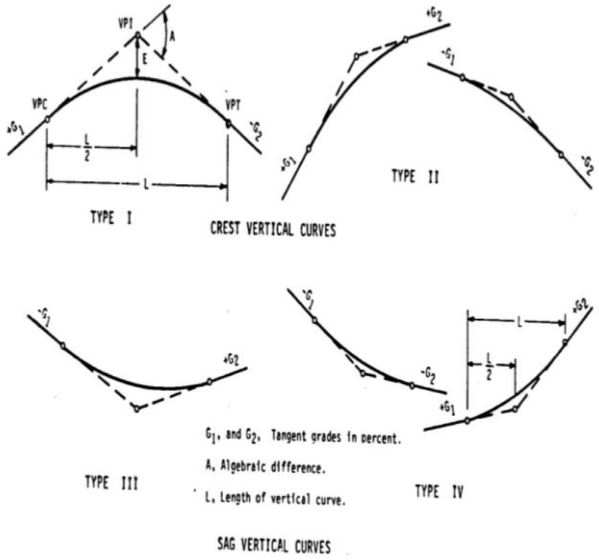

Fig -2: Sample representation of Vertical curve

Junction geometry: The Road Intersections are the critical elements of the Road sections and the function of a designed intersection is to control conflicting and merging streams of traffic. The design of junction includes the determination of the lane widths required including the auxiliary lanes, traffic control devices and channelization, sufficient turning radii etc. The general design principles of intersection design include design of the approach speeds, restriction on available land, sight distance available.

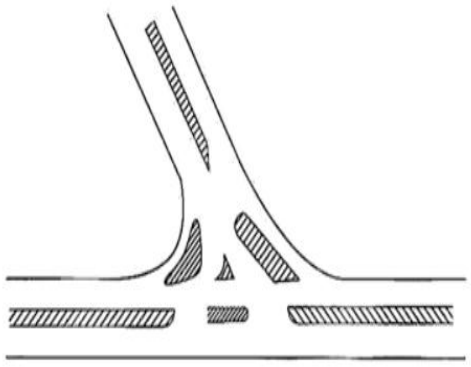

Fig -3: Sample representation of a Channelized Intersection

2. OBJECTIVES

- The main objective of the study is to examine the existing road geometry and its contribution in the road safety measures for reducing accidents and therefore reducing long term cost.
- To identify the safety issues in highway design to meet the needs of all types of road users and to minimize the conflict with one another.
- To analyze all accident black spots and convert them into non accidental prone areas and thus finding improvement scope in the road geometry with some measures.
- To increase awareness about safe design practices which involve in the planning, design, construction and maintenance of roads.

3. LITERATURE REVIW

In the past few decades, many studies have been conducted to identify and to solve complex traffic and transportation engineering problems. The study has considered several reviews of published and unpublished research studies and related material for building the foundation of the study. The study will help the researchers to find the deficiency in the roadway design and to establish the level of safety of the study area, which will let Authorities/Agencies, avoid the future occurring cost i.e., construction or accident cost.

4. METHODOLOGY

It is proposed to study design consistency of the road to assess the level of safety for the major district road starting from Raghunathpally at CH 0+000 and ending at Narmetta Cross Road Junction CH:22+310 in Warangal district in Telangana. Various factors affecting level of safety in the study are studied. Detailed Primary and Secondary Data for the selected road is collected from companies and various Government organizations and analyzed for any design

deficiency in Horizontal or Vatical alignment. For assessing the roadway design various parameters are considered and a checklist is prepared based on IRC and AASTHO and DMRB codes. With a view of getting results both the primary and secondary data are interpreted, and results are drawn, and a level of safety is assigned to the road.

5. DATA ANALYSIS & DISCUSSIONS

The plan and profile design drawings and the data collected, are thoroughly studied, and analyzed based on the proposed methodology. Following observations were noted:

For Horizontal Alignment: Horizontal alignment includes the design of horizontal curves, extra widening, deflection angle, transition lengths, speed, broken back curves, super elevation, The horizontal alignment data based on the plan and profile is analyzed step by step and the observation related to each design element is recorded:

- Design of horizontal curves:

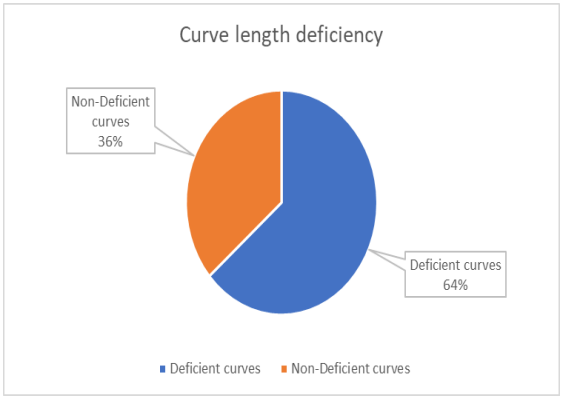

Chart -1: Graph showing % of curve length deficiency

- Extra widening:

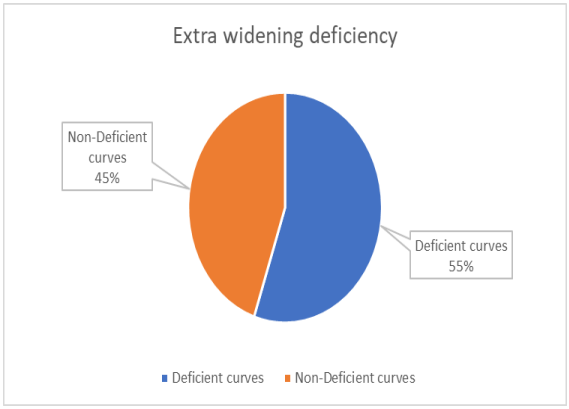

Chart -2: Graph showing % of extra widening deficiency

- Sharp curves:

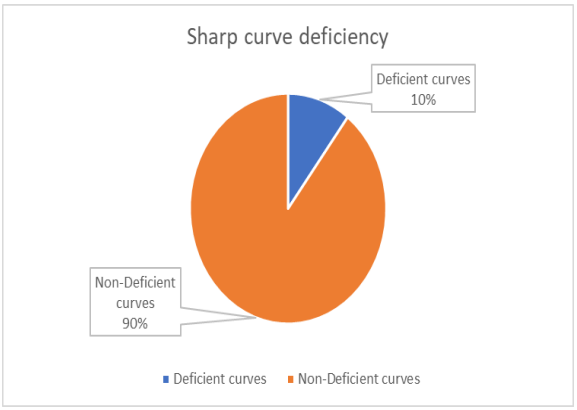

Chart -3: Graph showing % of sharp curve deficiency

- Transition length:

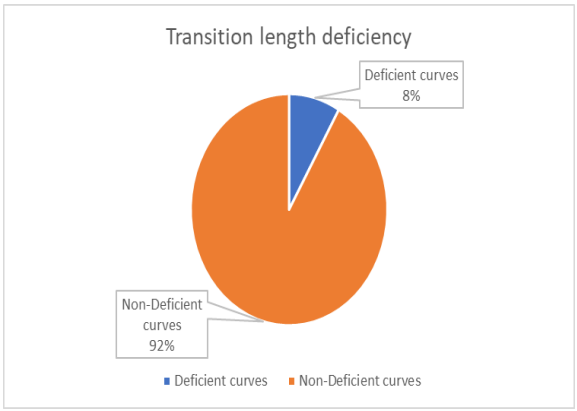

Chart -4: Graph showing % of missing transition length deficiency

- Speed: Based on the speeds observed in the road design, following speed management plan to be followed for a better level of safety:

Table -1: Speed applicable in the sections

S. No	Chainage		Length of section	Maximum allowable speed limits
	From	To		
	0+000	0+700	700	Raghunathpally (30 KPH)
	0+700	4+500	3800	65 KPH
	4+500	5+500	1000	Kilasapuram (20 KPH)
	5+500	10+200	4700	65 KPH
	10+200	10+800	600	Graves (30 KPH)
	10+800	11+200	400	Mekalagattu (20 KPH)
	11+200	11+500	300	20 KPH

S. No	Chainage		Length of section	Maximum allowable speed limits
	From	To		
	11+500	12+300	800	Gidhebanda Thanda (20 KPH)
	12+300	13+850	1550	65 KPH
	13+850	14+400	550	Structures (20 KPH)
	14+400	14+900	500	65 KPH
	14+900	15+200	300	Graves (30 KPH)
	15+200	17+000	1800	Machapahad (20 KPH)
	17+000	19+000	2000	65 KPH
	19+000	19+700	700	Aagapeta (20 KPH)
	19+700	21+700	2000	65 KPH
	21+700	22+310	610	Narmetta (30 KPH)

For Vertical Alignment: Vertical alignment includes the design of vertical curves, sight distance, up or down gradients. Vertical curve is applied for smooth and safe transition between two grades. Vertical alignment governs the design of profile is the vertical aspect of the road. The vertical alignment data based on the plan and profile is analyzed step by step and the observation related to each design element is recorded:

- Vertical Intersection Point (VIP) to Vertical Intersection Point (VIP) distance

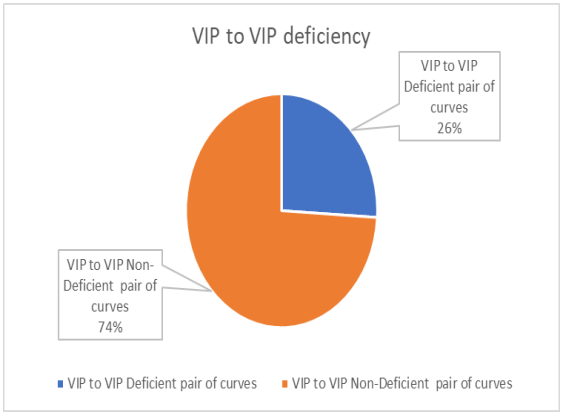

Chart -5: Graph showing % of VIP to VIP deficiency

- Longitudinal gradient

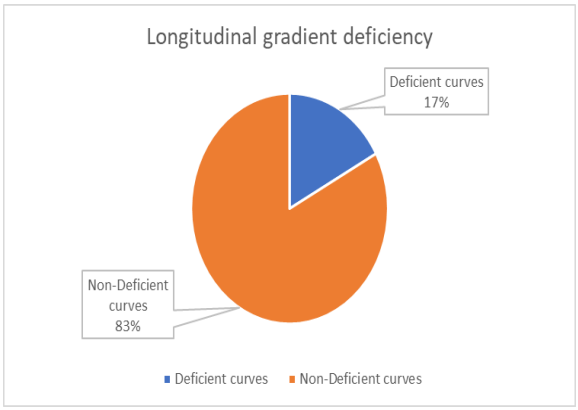

Chart -6: Graph showing % of longitudinal gradient deficiency

- Raised finished road level (FRL) at built ups sections

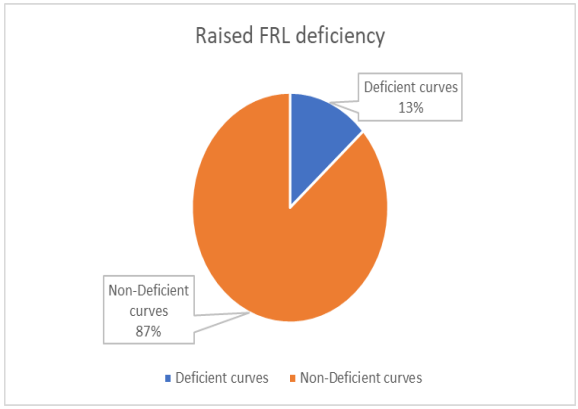

Chart -7: Graph showing % of raised FRL deficiency

- Design of sight distance for vertical curves

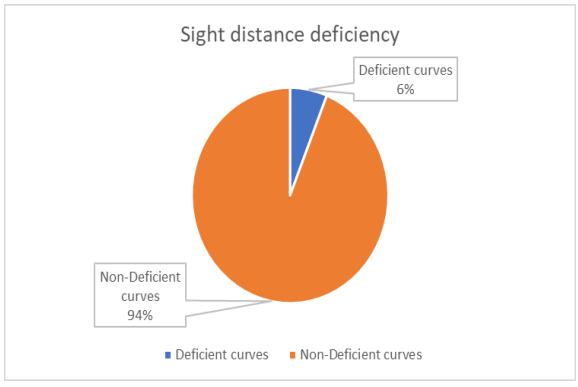

Chart -8: Graph showing % of sight distance deficiency

For Junction geometry: The Road Intersections are the critical elements of the Road sections and thus their design affects the level of safety. The design of junction includes the determination of the lane widths, turning radii, sight distance, channelization, and its area, swept paths, traffic control devices etc. The general design principles of

intersection design also include design of the approach speed and restriction on the available land Following Observation are recorded at major intersections at CH 0+000, CH 1+160, CH 22+310.

1. Layout at major intersections is not channelized which is a major safety issue, hence the to make traffic flow effective junctions to be channelized.
2. No proper road sign and markings are present on the approaches to the junction.
3. Visibility at junction approaches is a safety deficiency which is to be designed for junction approaches.

6. CONCLUSIONS

Following conclusions can be made from the research:

- **For Horizontal design**

Table -2: Table showing Horizontal design deficiencies:

S. No	Description	Number of curves	Percent of deficient curves
1.	Total number of Horizontal curves	154	-
2.	Deficient curves for curves lengths	98	64
3.	Deficient curves for extra widening	85	55
4.	Sharp curves	16	10
5.	Deficient curves for transition lengths	13	8

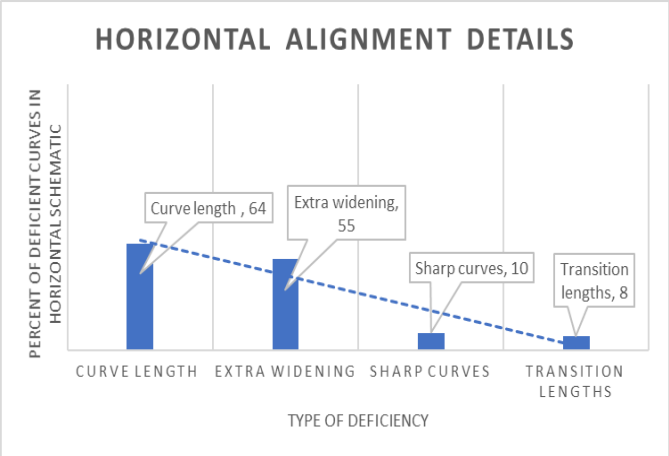

Chart -9: Graph showing Horizontal design deficiencies

- **For Vertical design**

Table -3: Table showing Vertical design deficiencies:

S. No	Description	Number of curves	Percent of deficient curves
	Total number of Vertical curves	82	
	Deficient curves for VIP to VIP	21 pairs	26
	Deficient curves for Longitudinal gradient	14	17
	Deficient curves for FRL	11	13
	Deficient curves for Sight distance	5	6

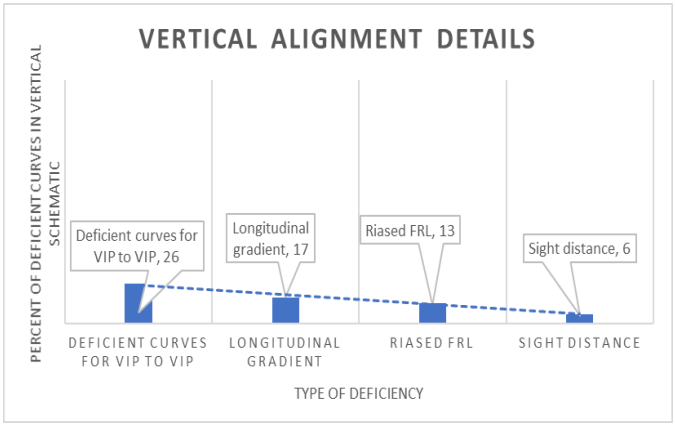

Chart -10: Graph showing Vertical design deficiencies

- Based on the trends of inconsistency found in the design, the road can be said at low level of safety for the traffic. Moreover, the time or cost which will be required to eliminate the unsafe elements in the designs, requires major reconstruction which is an indicator of cost again.
- Horizontal alignment in villages or built-up area is substandard and is not safe for commercial vehicles/heavy vehicles to pass through. Moreover, the available width between buildings is barely sufficient for the standard cross section to fit in. Therefore, as a long-term solution a bypass/realignment of the existing road should be considered to improve the geometry and enhance safety to road users
- The study and research would be helpful in finding accidental prone areas which were due to poor geometric design or the areas where accidents are likely to happen, all these can be minimized by improving the

geometry of road & increasing level of safety by adopting temporary remedial measure which will overall be reducing the accidental cases.

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BIOGRAPHIES

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Hemant Agrawal is working as an Assistant Professor in Department of Civil Engineering Jagannath University Jaipur. Graduated from Rajasthan Technical University, Kota with honor's in 2014. He is honored with a gold medal in M. tech and has published 6 papers in International and National Journals & 3 in National Conference. He has more than 5 years of teaching experience. His area of interest is Structure analysis, Concrete application etc.

Professor (Dr.) Bharat Nagar is working as a HOD and M. Tech Coordinator in Department of Civil Engineering, Jagannath University Jaipur since last 11 years. He has worked in various engineering colleges and industries in Rajasthan & has total experience of more than 17 years. He has written 4 books and more than 50 research papers in various reputed International and National Journals. His area of interest is Environmental Assessment, Concrete application, and Earthquake Engineering etc.