Design of Horizontal and vertical alignment of Expressway for the speed of 150kmph – 'A Review'

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***Abstract* - The design of roads is an important aspect in the development of road infrastructures which significantly impacts the economy, environment and society of the region. The design of road alignments, which defines how the road will traverse the terrain and geography, is particularly interesting as there can be virtually infinite number of alternatives on how the road alignment is planned based on design speed. There is a need to carefully design the alignment for that road alignment to be most economical, environmentally friendly, comply with society and promote good transportation. The Objective of this journal is to propose a method that the project highway will be designed for the speed of 150kmph, and it should be economical, geometrically satisfied and feasible. While designing the horizontal alignment several factors shall be taken e.g., sight distance for good visibility, desirable radius, adequate transition curve etc. and at the time of vertical alignment design, it is to be take care that there should not be higher cutting or filling to minimize the earthwork. It makes the project economical.**

I.INTRODUCTION

Geometric design is concerned with the design of all the visible features of the roadway". The purpose of geometric design is to provide safety and mobility to road users. To achieve these varied objectives, designers use various methods and criteria. This practice results in enhanced safety, mobility, accessibility and performance of the transit network.

Traditionally the roadway design has always focused on the provision of minimum design standards to the design elements and completely neglecting the performance characteristics. With the intention of attaining such multifaceted standards each phase and model involved in the process of development of the alignment involves defining relationships between various design parameters and the objectives such as safety and consistency.

Design of an expressway is an even more challenging element in the design process. For this purpose, the

Indian Road Congress has developed some specific design standards for the design of this expressway namely IRC: SP:99-2013. It suggests that the expressway shall be planned as a "fully access controlled highway" by providing entry and exit points at predetermined locations using properly designed entry/exit ramps and interchanges. To improve the mobility and to save in the generalized cost of travel the design speed has to be constantly increased to 120 km/hr as suggested by the IRC: SP:99-2013. This needs further control of the entry and exits and dire need of taking safety and consistency into consideration.

To co-ordinate the design of elements and performance objectives, there is a need to develop relationships between various geometric design parameters and certain variables which representative of the objectives like safety and consistency. So, roadway design should be dynamic and change over time as the research as well as resources change

II.DATA DESCRIPTION AND TERMINOLOGY

A. Design Speed:

The design speed of main carriageway (MCW) shall be 150kmph for the plain and rolling terrain.

B. The Radius of Horizontal curves:

The radius of horizontal curve is governed by two factors:

1. The design speed and allowable superelevation and friction
2. The minimum turning radius of design vehicle.

R=V2/127(emax+f) (i)

Where,

V = design speed of main carriageway =150kmph
e max = maximum superelevation provided = 7% (as per IRC:SP:99-2013)
f = lateral/side friction for the design speed
As per IRC: SP:99-2013 the following model has been developed to predict the friction factor
f = 0.179 - 0.000675*Design Speed
f = 0.179-0.000675*150 = 0.7775~0.08 (ii)
R(abs)min= [{(150)^2}/{127(0.07+0.08)}]
= 1181.102 m ~ 1200 m

Absolute Minimum radius required for the speed of 150kmph is 1200m (iii)
Desirable minimum - Calculated by assuming 50% of the value of lateral friction factor
R(des)min=[{(150)^2}/{127(0.07+0.04)}]
=1610.59 m~1700 m

Desirable Minimum radius required for the speed of 150kmph is 1700m (iv)
Radius required for the location of the main carriageway not requiring any superelevation
R= V2/(225*camber)
As per IRC SP 99 2013 Clause 2.8 if Annual rainfall is more than 1000mm than cross fall shall be 2.5%. else 2.0%
For camber 2.0%, R= [{150) ^2}/(225*0.02)]=5000m
For camber 2.5%, R= [{150) ^2}/(225*0.02)]=4000m

Minimum radius for no superelevation required is 5000m (v)

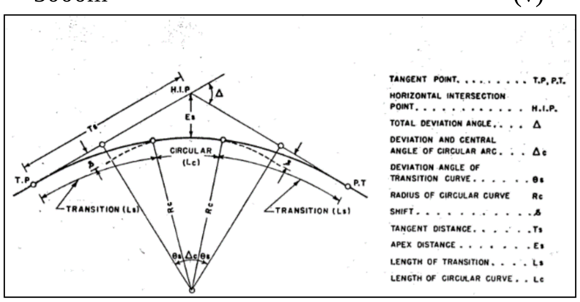

Fig.1 Elements of a combined horizontal circular and transition curve

C. *Transition curve:* When a vehicle travels from the straight to a curve of finite radius, it is suddenly subjected to an outward centrifugal force. This causes a shock and sway to the passenger and the driver. transition curve has tendency to smoothly turn from straight to a curve and improve the aesthetic appearance of road.

(a) Transition curve length:
Method-1: Rate of change of centrifugal acceleration
Ls=0.0215V3/c*R
c=80/(75+V) =80/ (75+150) = 0.36 < 0.5
Take c=0.5
Ls= (0.0215*150^3)/(0.5*1050)=138 m ~140 m
Method-2: Rate of change of super-elevation
Ls=2.7V^2/R
Ls=2.7*150^2/1050=57.85 m
Method-3: Rate of change of super-elevation
Ls= e*W*N
e = superelevation = 5%
W = Roadway width =11.25m (for six lane road)
N= Rate of change of superelevation = 1 in 200 (for plain & rolling terrain)
Ls = .05*11.25*200 = 112.5 ~ 115m
Method 4: To be on safe side, desirable lengths of spiral transition curves are correspond to 3.0s of travel time at the design speed of the roadway because it requires at least 3 seconds for the driver to steer one direction.
Ls = v*t
V = design speed (m/s) = 150kmph = 41.66mps
t = time taken to turn the vehicle (s) = 3sec
Ls = 41.66*3 = 124.98 ~ 125m
Required Ls shall be maximum of all fourth methods

Minimum transition length shall be provided for the speed of 150kmph is 125m (vi)

D. Sight distance

Sight distance is the length of roadway visible to a driver. Majorly these following three types of sight distances are considered in expressway design.
(a) Stopping sight distance, (b) Intermediate sight distance and (c) Passing sight distance
(a) Stopping sight distance (SSD)= Stopping sight distance (SSD) is the minimum sight distance available on a highway at any spot having sufficient length to enable the driver to stop a vehicle traveling at design speed, safely without collision with any other obstruction.
SSD = .0278*V*t+V2/(2*g*f)
Where,
V = design speed = 150kmph
t = reaction time = 2.5sec (as per PIEV theory)
g = gravity =9.81m/s2

f = lateral friction = 0.35

SSD = [(0.278*150*2.5) +(150^2)/ (2*9.81*0.35)]

SSD = 357.343 m~ 360 m (vii)

(b) Intermediate sight distance (ISD)= It is defined as twice of SSD

ISD= 2*SSD = 2*360 = 720m (viii)

(c) Decision sight distance (DSD)= At critical locations or decision points where changes in cross-sections occur such as toll plazas and interchanges, the sight distance shall not be less than the decision sight distance.

Decision Sight Distance (DSD)=0.278*V*t

V=design speed = 150kmph and t =10.2 (as per exhibit 3.3 of AASHTO)

DSD = 0.278*150*10.2 = 425.34 ~ 430 (ix)

E. Length of vertical curve:

Length of vertical curve classified into three categories and the maximum length of the following three shall be provided.

(a) Minimum length of vertical curve, (b)Length of vertical curve for SSD and (c) Length of vertical curve for ISD

(a) Minimum length of vertical curve is equal to 0.85 times the design speed in kmph as per IRC:SP:99

Lc= 0.85*150 = 127.5 ~ 130m (x)

(b) Length of vertical curve for SSD, where S =360m

(i) If length of vertical curve is more than SSD (L>S)

Lc = NS2/4.4

N = grade change = let's suppose grade change is 1%

Lc = (.01*360^2)/4.4 = 294.5m (Fail)

(ii) If length of vertical curve is less than SSD (L<S)

Lc = 2S-4.4/S

Lc = (2*360) - (4.4/360) = 280m (Pass)

Here equation (ii) satisfies,

Lc = 280, (280 is less than 360m)

Take this value (equation satisfies the condition)

The length of vertical curve for the grade difference 1% and speed 150kmph is 280

*Length of vertical curve depends on grade difference

(c) Length of vertical curve for ISD (where S =720m)

(i) If length of vertical curve is more than ISD (L>S)

Lc = NS2/9.6

N = grade change = let's suppose grade change is 1%

Lc = (.01*720^2)/9.6 = 540 (Fail)

(ii)If length of vertical curve is less than ISD (L<S)

Lc = 2S-4.4/S = (2*720) -(4.4/720) =480 (pass)

Lc = 480, (480 is less than 720m)

Take this value (equation satisfies the condition)

The length of vertical curve for the grade difference 1% and speed 150kmph is 480

*Length of vertical curve depends on grade difference

F. K-Value:

This value represents the horizontal distance along which a 1% change in grade occurs on the vertical curve. It expresses the abruptness of the grade change in a single value. Speed tables or other design tools often provide a target minimum K value.

K=L/N

L = length of vertical curve

N = Grade change

L = 295 for SSD (from clause E(b))

L = 540 for SSD (from clause E(c))

K = 295 for SSD (K value is constant for any grade change) (xi)

K = 540 for ISD (K value is constant for any grade change) (xii)

III. CONCLUSIONS

This paper presented the geometric design parameter based on Previous studies, Aastho and IRC codes. The results shows that the expressway can be designed for the speed of 150kmph. As of now the IRC codes provide the details for the speed of maximum 120kmph and that should be increased. As various safety parameters have been taken for expressways that increase the cost of road also. Study says that most of accident happens because of the high speed. So using the following parameters expressway can be designed for the speed of 150kph however operational speed can be reduced using sign board so that nobody jump the operational speed and if someone crosses, he can run his vehicle smoothly without any consequences as the design speed is more than posted speed. All the geometric parameters are classified like horizontal curve, transition curves, sight distance, vertical curves etc.

The Geometric values are given in the following table.

Table 1: Geometric parameters

Description	Geometric Parameter		Remarks
	As per IRC: SP: 99-2013	As Per Calculation	
Speed	120km/h	150km/h	Clause-II(A)
Radius of horizontal curve	Abs min- 670m Des min – 1000m	Abs min – 1200m Des min – 1700m	Eq. (iii) and (iv)

Max Superelevation	7% (if R<Des min) 5% (if R>Des min)	7% (if R<Des min) 5% (if R>Des min)	Standard (IRC:SP:99 - 2013)
Radius not requiring Superelevation	3500m	5000m	Eq. (v)
Camber/cross fall	2.5% (if annual rainfall >1000mm) 2.0% (if annual rainfall < 1000mm)	2.5% (if annual rainfall >1000mm) 2.0% (if annual rainfall < 1000mm)	Standard (IRC:SP:99 - 2013)
Minimum length of transition curve	Ls = 85m	Ls= 125m	Eq. (vi)
Sight distance	SSD=250m ISD=500m DSD=360m	SSD=360m ISD=720m DSD=430m	Eq. (vii) Eq. (viii) Eq. (ix)
Minimum length of vertical curve	100m	130m	Eq. (x)
K value	SSD=142 ISD=260.5	SSD=295 ISD=540	Eq. (xi) Eq. (xii)

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