Safety in Road Design

Tena Bridge

Mumbai-Pune Expressway

Mumbai-Pune Old status

Topography Affects Geometric Design

Kathipara Interchange, Chennai

Design Controls and Criteria

- Design speed
- Topography
- Traffic factors
- Design hourly volume and capacity
- Environmental and other factors

Suggested design speeds in kmph for rural highways

Table 2. Design Speed (IRC:73-1980)

	Plain		Rolling		Mountainous		Steep	
	R	M	R	M	R	M	R	M
NH and SH	100	80	80	65	50	40	40	30
MDR	80	65	65	50	40	30	30	20
ODR	65	50	50	40	30	25	25	20
VR	50	40	40	35	25	20	25	20

R: Ruling

M: Minimum

Suggested design speeds in kmph for urban streets in India

Table1. Design Speed (IRC : 86-1983)

Classification	Design Speed (km/hr)
Arterial	80
Sub-arterial	60
Collector street	50
Local street	30

Traffic

- Traffic volume indicates level of service for which highway is being planned and directly affects width, alignment, grades.
- Design Hour Traffic Volume: Unit of measuring traffic volume is Annual Average Daily Traffic volume (AADT).
- It is equal to the total annual volume of traffic divided by the number of days in a year.
- It is easy to calculate when continuous traffic count is done at a point on the highway.
- AADT does not help in geometric design as it does not reflect monthly, weekly, daily or hourly variations of traffic

Traffic

- Commonly used unit is 30th Highest Hourly Volume (30HV).
- Defined as the hourly volume that is exceeded by 29 hourly volumes during a year.
- In American conditions: 30HV is about 15% of AADT on Rural Highways and 8-12% on urban streets.
- For Indian roads 8-10% of AADT has been suggested as 30HV.

Directional Distribution of Traffic

- For 2-lane highways, design hour volume is the total traffic in both directions of travel
- For highways with more than 2 lanes, it is desirable to know directional distribution
- If not available, 67% of total traffic in one direction for design purposes.
- Need to consider both morning and evening peak traffic volume

Traffic Composition

- Traffic is heterogeneous in character and consists of fast driven cars, trucks, buses, animal drawn vehicles.
- Passenger car units (PCU) or Passenger Car Equivalents (PCEs)
- PCU for different vehicles do not remain constant for all times. Important factors which contribute in determining PCU are:

➢ Average length and width of vehicle

➢ Average speed of vehicle

➢ Average gap both transverse and lateral distance between vehicles

PCU for Rural Conditions in India

Table1. Recommended PCU factors for Various types of vehicles on Rural Roads (IRC : 64-1990)

Passenger car, pick-up van, auto-rickshaw ………….. 1.0

Motor-cycles, scooters ………………………………….. 0.5

Agricultural tractor, Light Commercial Vehicle ………… 1.5

Truck or Bus ……………………………………………… 3.0

Tractor-trailer, Agricultural tractor-trailer ………………. 4.5

Cycle Rickshaw …………………………………………… 2.0

Hand cart ………………………………………………….. 3.0

Horse-drawn vehicle ……………………………………… 4.0

Bullock cart ……………………………………………… 6.0-8.0

Design Controls

Topography

Various design elements is related to topographical features.

Terrain is classified by means of cross-slope of the country i.e. slope approximately perpendicular to the CL of the highway location.

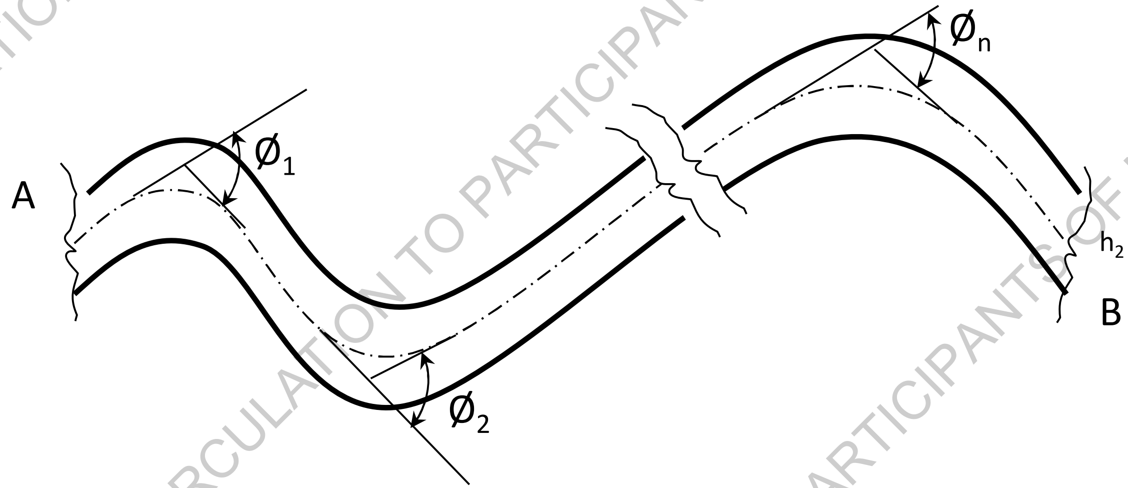
Table 1. Terrain Classification (IRC:73-1980)

Terrain classification	% slope of country
Level	0 to 10
Rolling	10 to 25
Mountainous	25 to 60
Steep	Greater than 60

Curvature and Longitudinal Profile

Average Curvature (CV)

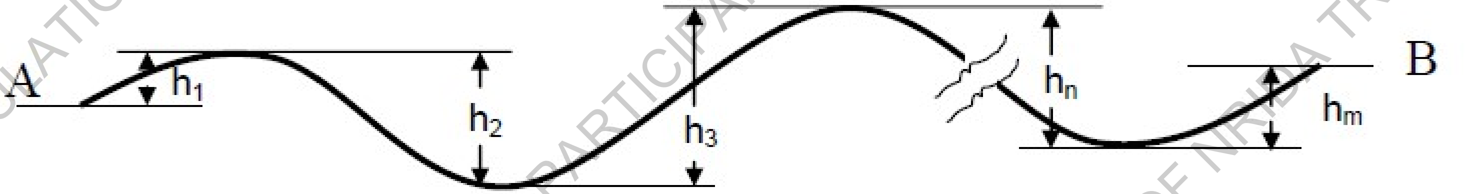
$= \Phi_1 + \Phi_2 + \Phi_3 \ldots / \text{Dist. In km (degrees/km)}$



Curvature and Longitudinal Profile

Longitudinal Profile (RS)

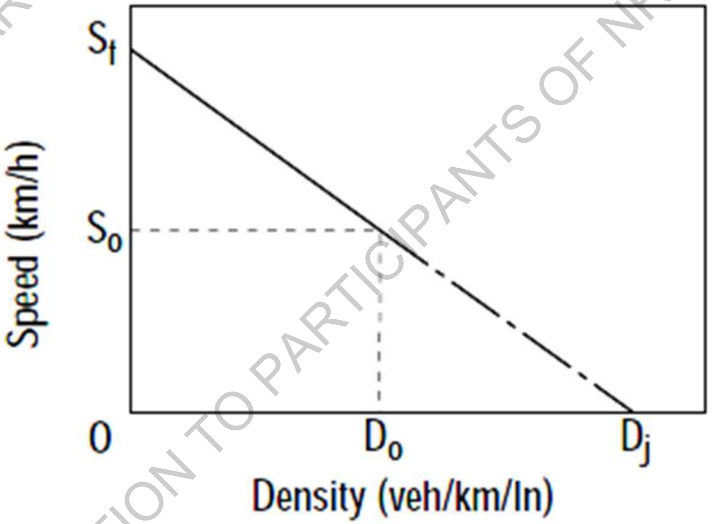
$= h_1+h_2+h_3..... h_n$ (metres)/ Distance in km (m/km)

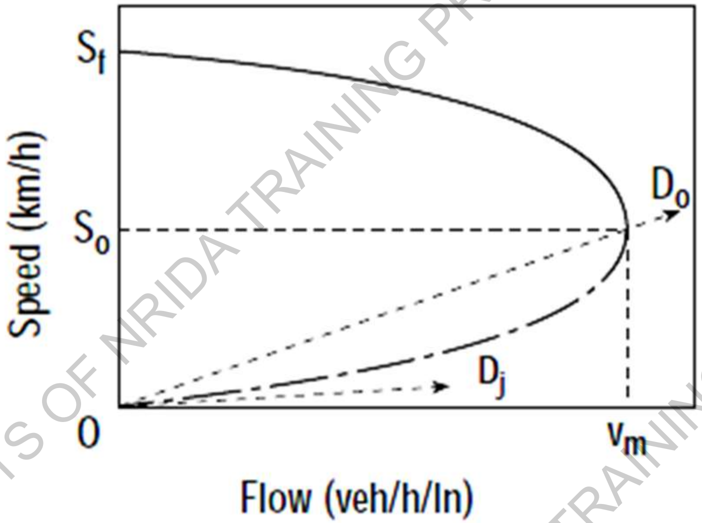


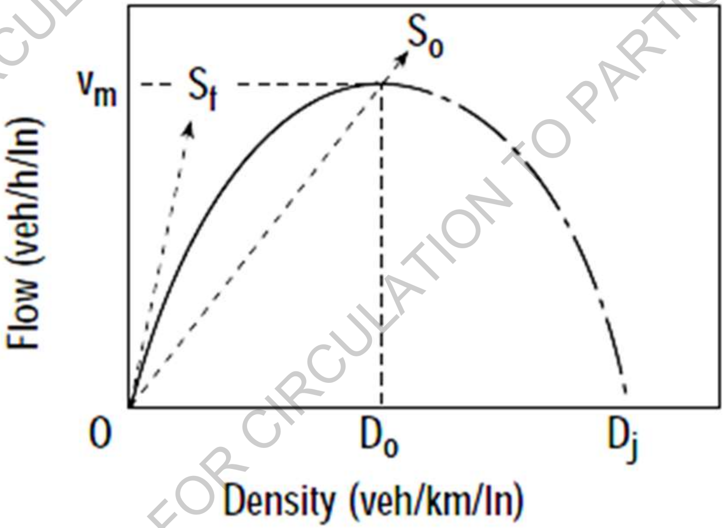
Two-lane highway capacity

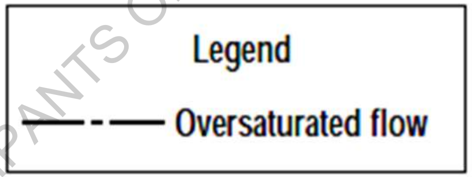
- Undivided with one lane for each direction
- Traffic operation is significantly different
- Overtaking is possible based on oncoming traffic
- With increase in traffic volume, drivers must adjust travel speed and ability to pass declines.
- Many two-lane highways connect major traffic generators and also acts as major traffic carrier.

Highway Capacity

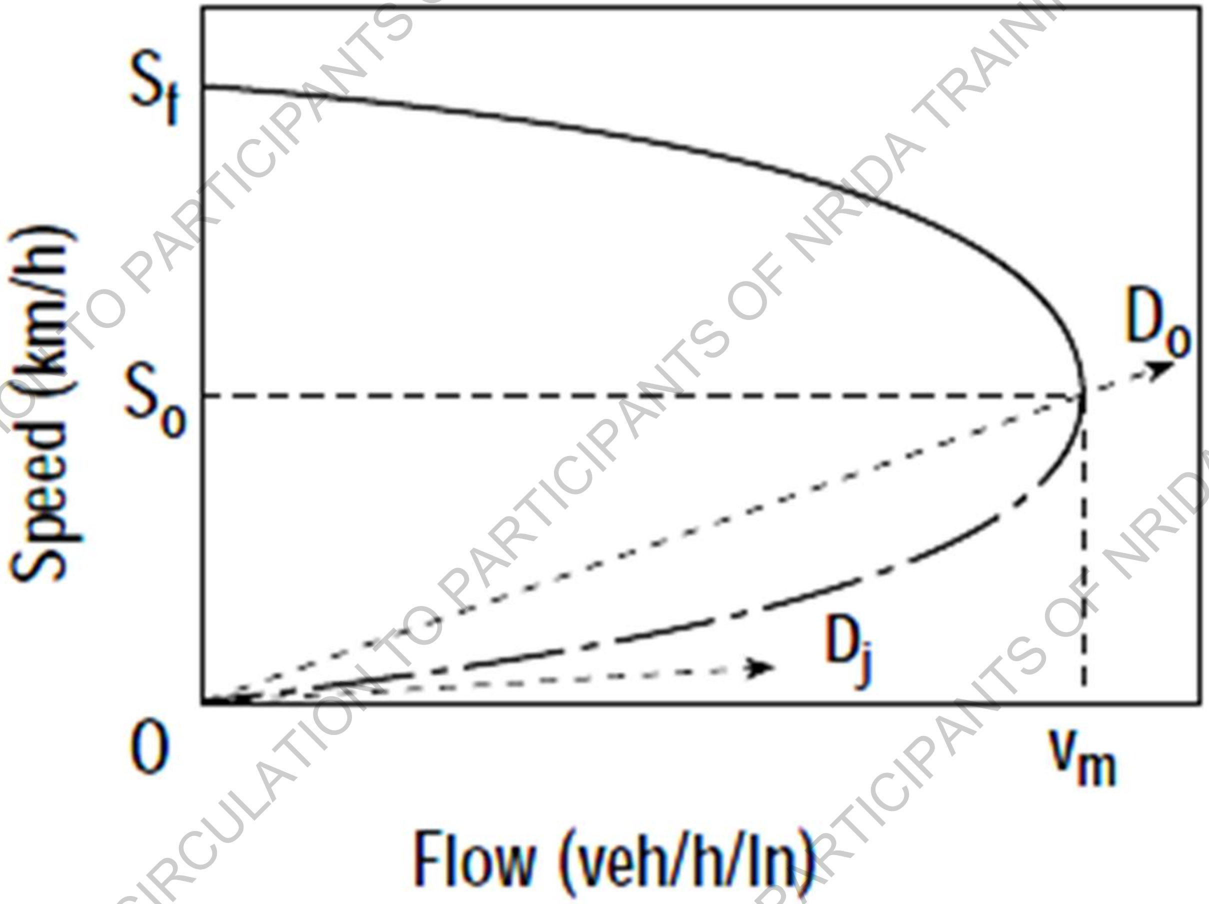




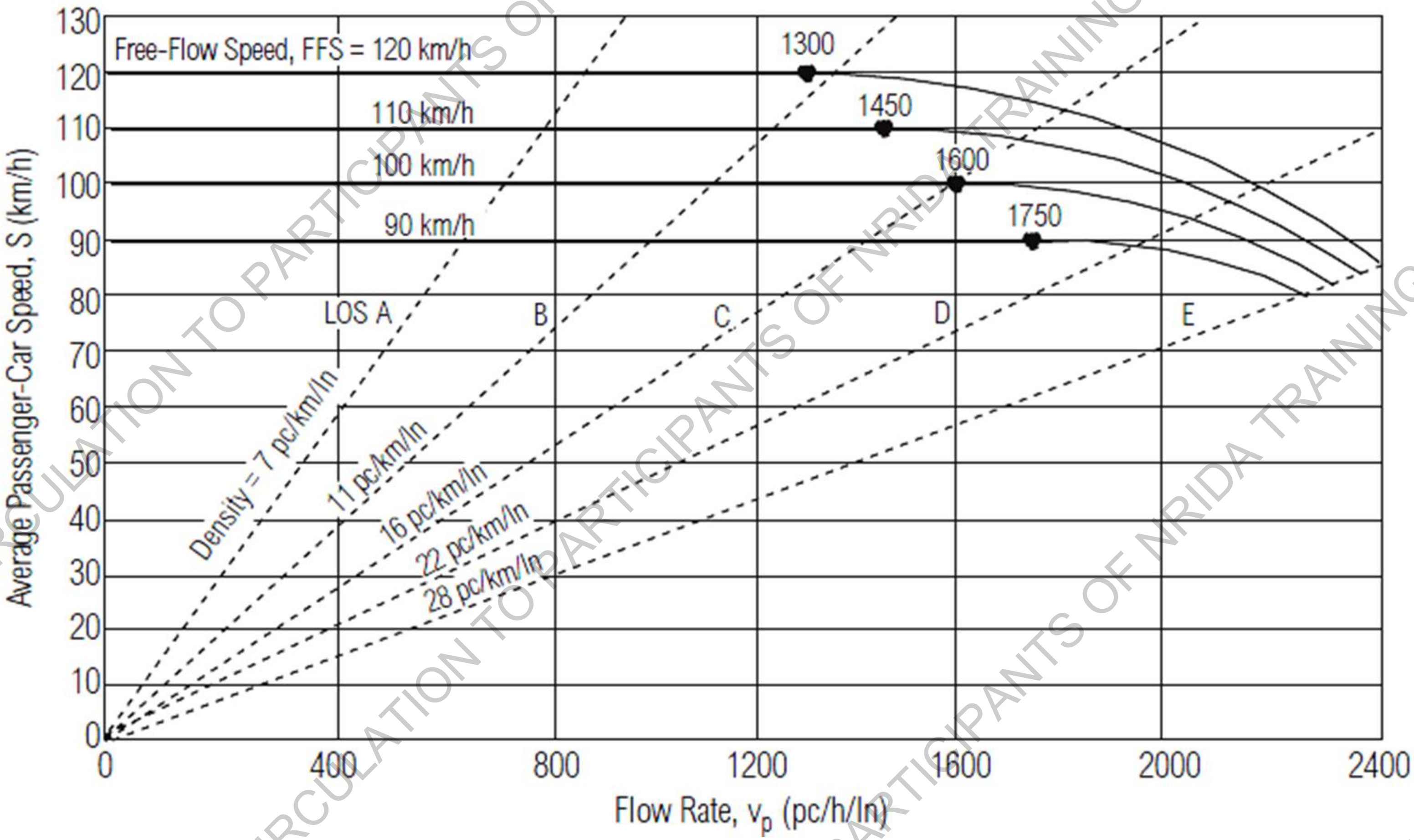




Highway Capacity



Highway Capacity on Multilane Roads



Levels of Service

- LOS A
  - Free-flow operation

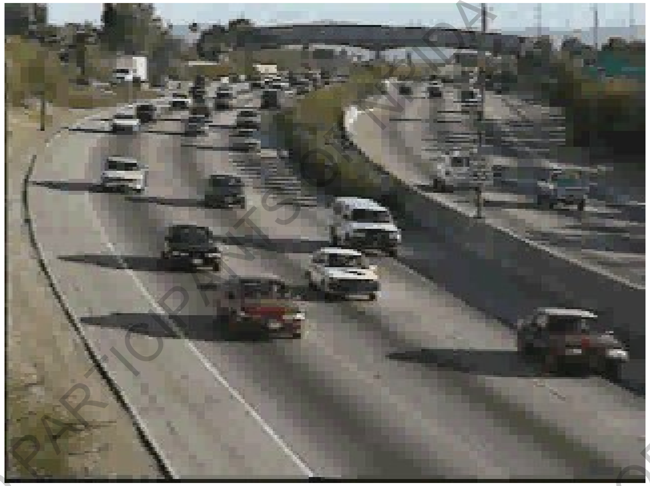
- LOS B
  - Reasonably free flow
  - Ability to maneuver is only slightly restricted
  - Effects of minor incidents still easily absorbed

From *Highway Capacity Manual*, 2000

Levels of Service

- LOS C
  - Speeds at or near FFS
  - Freedom to maneuver is noticeably restricted
  - Queues may form behind any significant blockage.

- LOS D
  - Speeds decline slightly with increasing flows
  - Density increases more quickly
  - Freedom to maneuver is more noticeably limited
  - Minor incidents create queuing

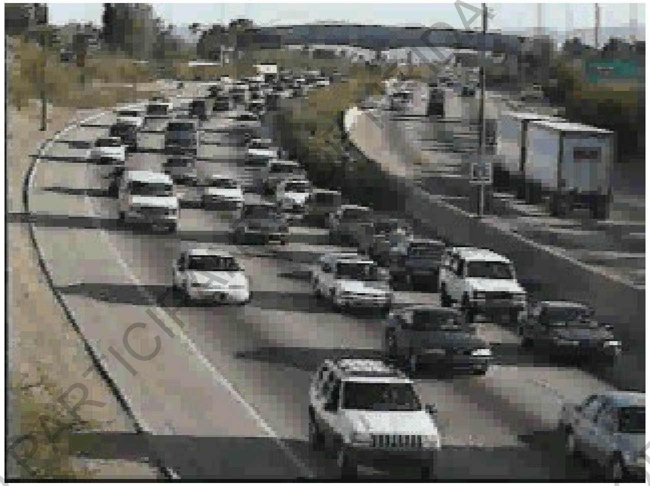


From *Highway Capacity Manual*, 2000

Levels of Service

- LOS E
  - Operation near or at capacity
  - No usable gaps in the traffic stream
  - Operations extremely volatile
  - Any disruption causes queuing

- LOS F
  - Breakdown in flow
  - Queues form behind breakdown points
  - Demand > capacity



From *Highway Capacity Manual*, 2000

Elements of Geometric Design

- Cross sectional elements
- Sight Distance
- Super elevation
- Extra widening
- Grades
- Horizontal Alignment
- Vertical Alignment

Cross-sectional elements

Right-of-way

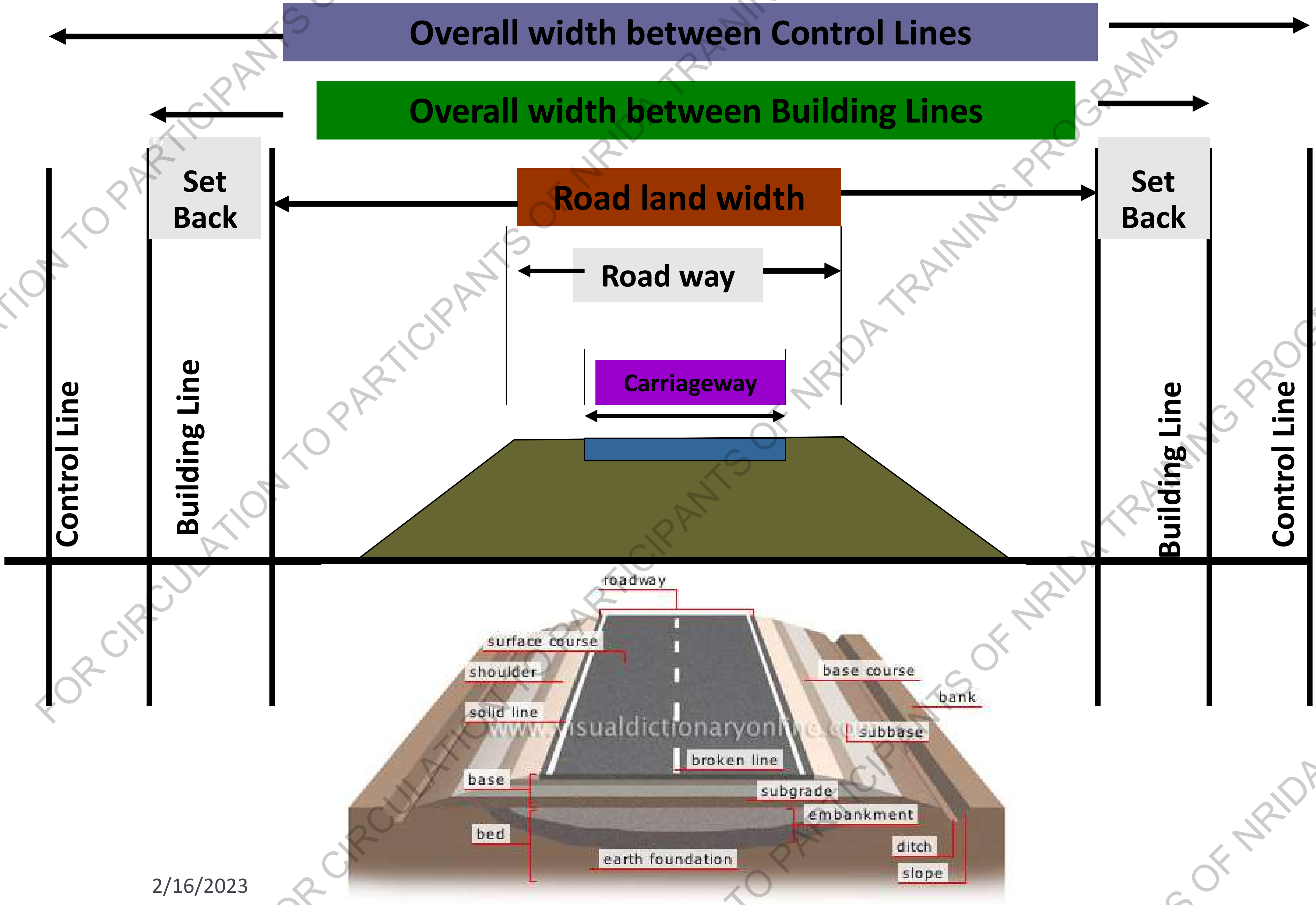
- Width of land secured and preserved in public interest for road development purposes. It should be adequate to accommodate all the elements that make-up cross-section of a road. Also space should be available for future development.

Control line:

- Represents the nearest limits of future uncontrolled building activity in relation to a road. Building activity not totally banned between the building line and control line, the nature of building is controlled.

Building line:

- Line, on either side of a road, between which and the road, no building activity is permitted.



Overall width between Control Lines
Overall width between Building Lines
Set Back
Road land width
Set Back
Road way
Carriageway
Control Line
Building Line
Building Line
Control Line
roadway
surface course
shoulder
solid line
www.visualdictionaryonline.com
broken line
base course
bank
subbase
base
subgrade
embankment
bed
earth foundation
ditch
slope

2/16/2023

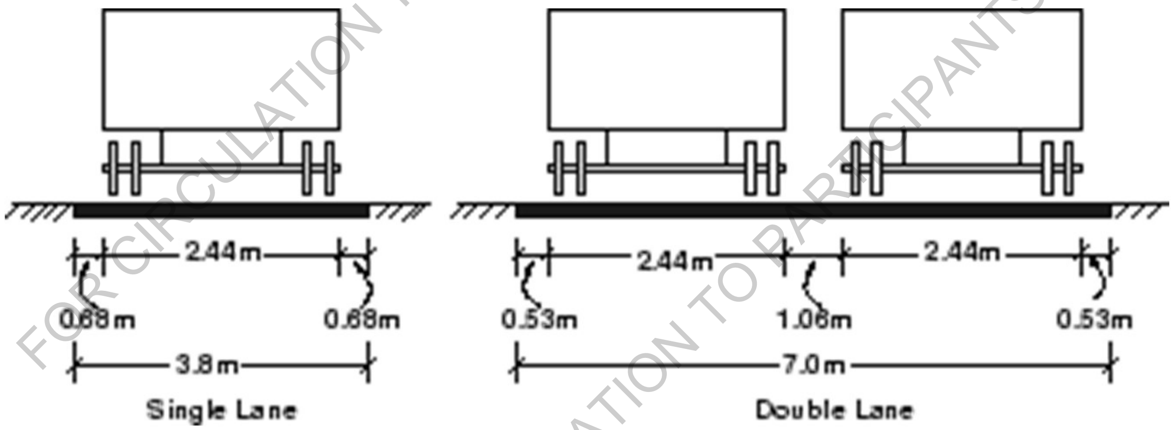
Right-of-way (in metre)

Table 3. Recommended Land width for different classes of Roads (IRC: 73-1980)

	Plain and rolling		Mountainous and steep	
	Rural	Urban	Rural	Urban
NH, SH	45 (30-60)	(30) 30-60	24	20
MDR	25 (25-30)	(20) 15-25	18	15
ODR	15 (15-25)	(15) 12-20	15	12
VR	12 (12-18)	(10) 10-15	9	9

Carriageway width

- Has profound influence on the capacity of a road. In India, a single lane pavement is generally 3.75m wide; A shoulder of 0.9m on either side is provided to facilitate overtaking and crossing operations.



Single lane	3.75 m
Two lane, no kerbs	7.0 m
Two lane, raised kerbs	7.5 m
Intermediate carriage	5.5 m
Multi-lane	3.5 m

Shoulders and Median

<u>Shoulders:</u>

- Portion of roadway intended for accommodation of stopped vehicles, emergency use and lateral support of base and surface courses.
- Current Indian practice for 2-lane roads suggested shoulder width is 2.5m.

<u>Median</u>

- Longitudinal space separating dual carriage-ways. Functions of medians are:
  - Separate opposing traffic streams, Minimize head light glare
  - Stopping area in case of emergency
  - 5m for rural highways (3m under restricted conditions)
  - 5m for urban is desirable, but 1.2m is acceptable.

Roadway width

Table 5,6. Width of roadway for single and two lane Roads in Plain, rolling, mountainous and steep Terrain(IRC: 73-1980)

	Plain and rolling	Mountainous and steep
NH and SH		
Single lane	12.0	6.25
Two-lane	12.0	8.8
MDR	9.0	4.75
ODR		
Single lane	7.5	4.75
Double lane	9.0	
VR	7.5	4.0

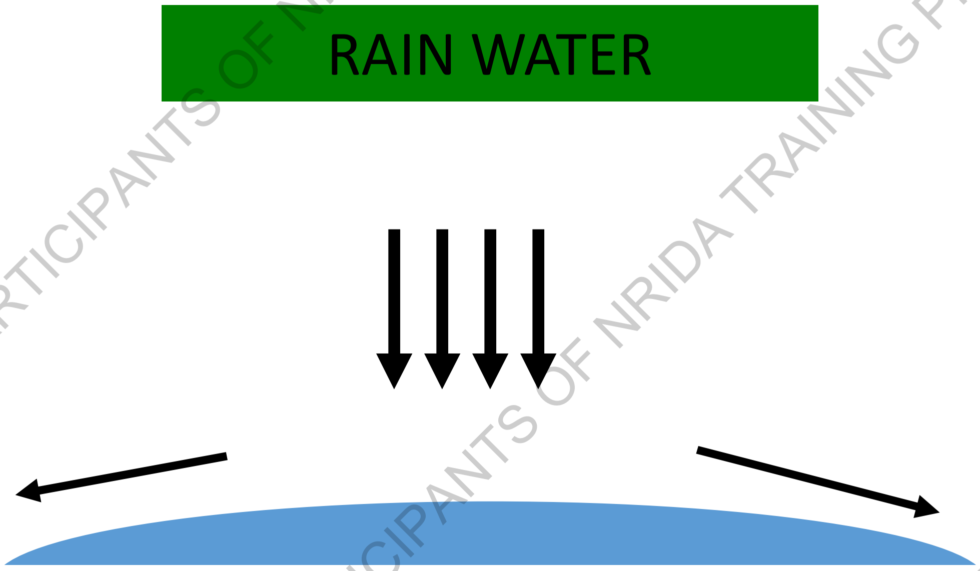
Camber

- Slope provided to road surface in the transverse direction for draining off rain water from road surface.
- Usually it is provided on straight stretches by raising the centre line of carriageway w.r.to edges forming a crown at the centre line.
- At horizontal curves, surface drainage is effected by raising outer edge of pavement w.r.to inner edge while providing desired super-elevation.

Type of camber depends on:

- Type of pavement surface
- Amount of rainfall in the area

Camber is provided as parabolic, elliptic or straight line shape.



NEED FOR CAMBER

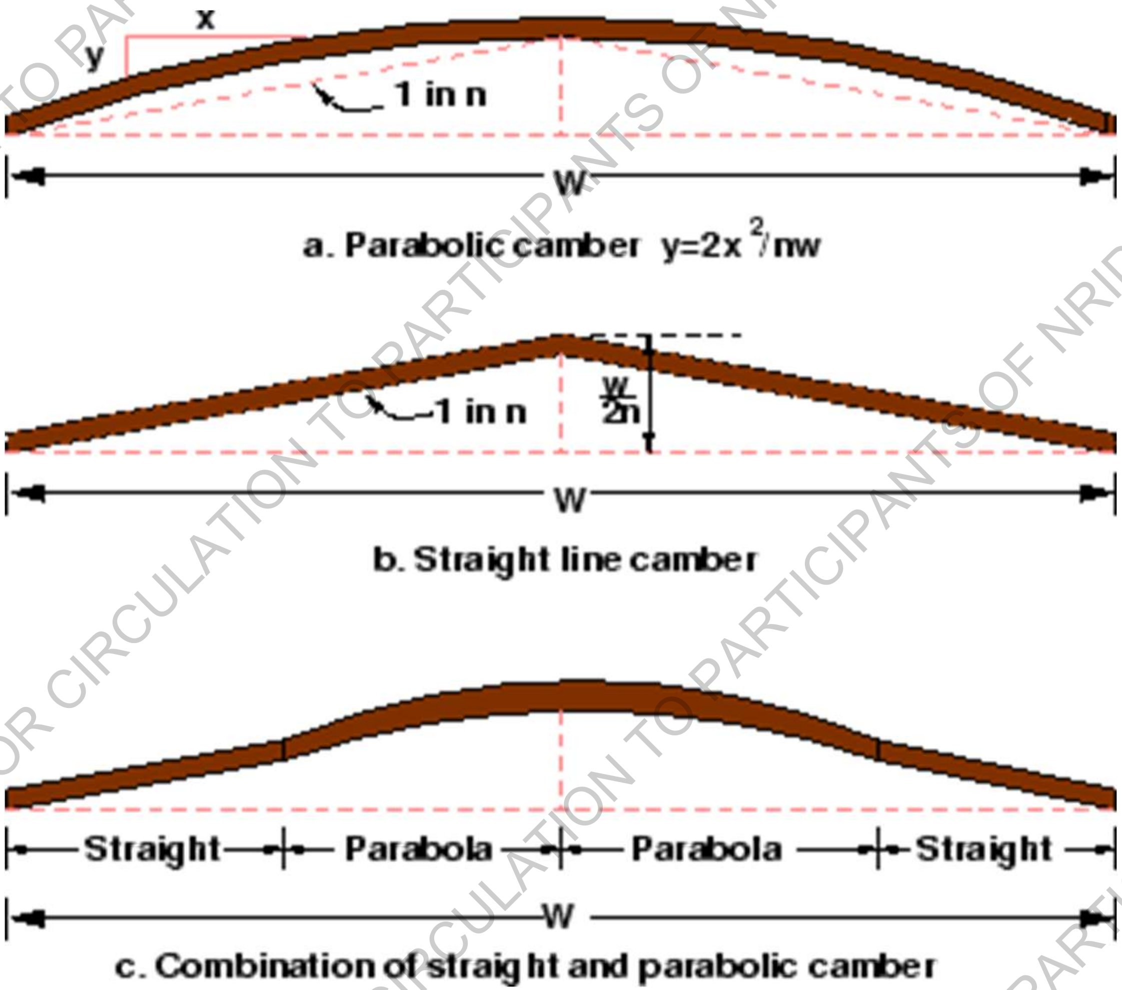
Camber

- Parabolic or elliptic is provided so that profile is flat at the middle and steeper towards edges. (Preferred by fast moving vehicles as they have to frequently cross the crown line during overtaking).

Table 8. Camber/Cross-fall Values for different Road surface types (IRC: 73-1980)

Road surface	Recommended camber
Earth road	1 in 33 to 1 in 25
Gravel road	1 in 40 to 1 in 33
WBM	1 in 40 to 1 in 33
Bituminous surface	1 in 50 to 1 in 40
Cement concrete	1 in 60 to 1 in 50

Types of Camber

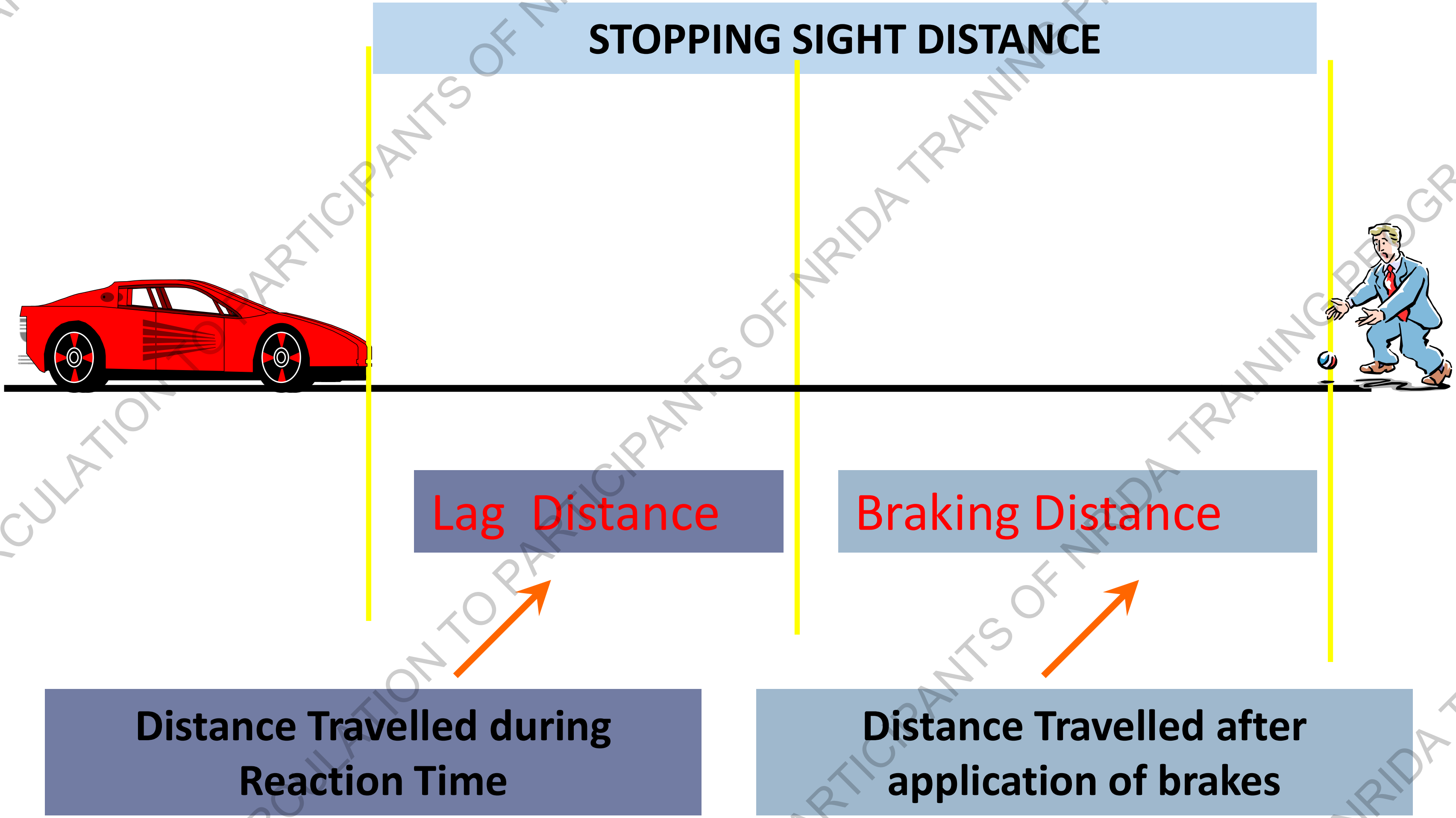


Surface type	Heavy rain	Light rain
Concrete/Bituminous	2 %	1.7 %
Gravel/WBM	3 %	2.5 %
Earthen	4 %	3.0 %

Stopping sight distance

- Highway with adequate sight ahead of a travelling vehicle results in safe operation.
- Distance along road surface at which a driver has visibility of objects, stationary or moving, at a specified height above carriage way is known as *sight distance.*
- **Stopping sight distance is the distance required by a driver of a vehicle travelling at a given speed to bring her/his vehicle to stop after an object on the roadway become visible.**
- **Stopping sight distance is made up of two components:**
  - ➢**distance travelled during perception and brake reaction time**
  - ➢**Distance travelled during the time brakes are under application till the vehicle stops.**

Stopping sight distance…

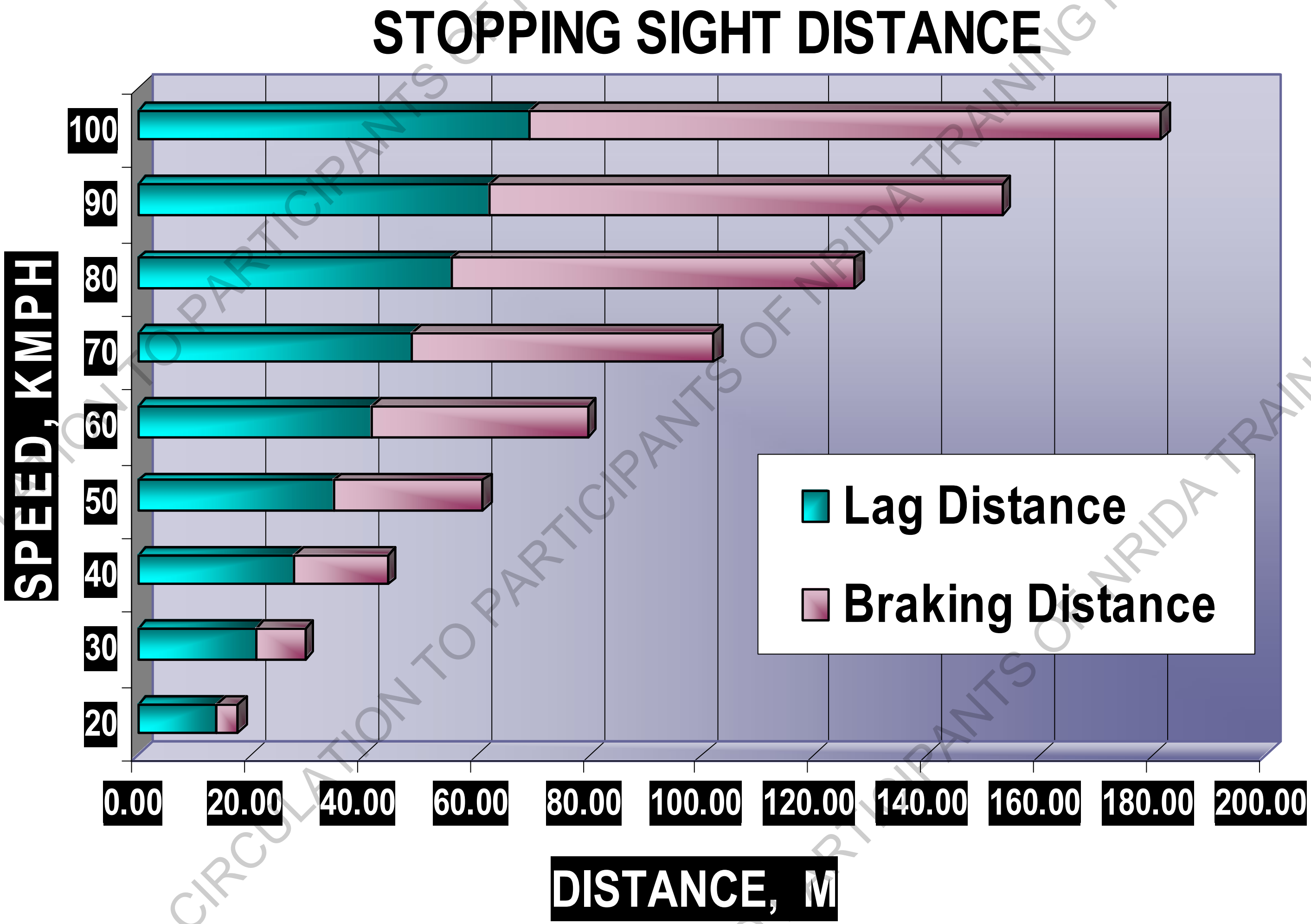


Stopping sight distance as per IRC

Table 1. Stopping Sight Distance on Rural Highways (IRC: 66-1976)

Design speed in kmph	Safe stopping sight distance (metres)
20	20
25	25
30	30
40	45
50	60
60	80
65	90
80	120
100	180

Stopping sight distance (IRC: 66-1976)



Locations where sight distances play major role

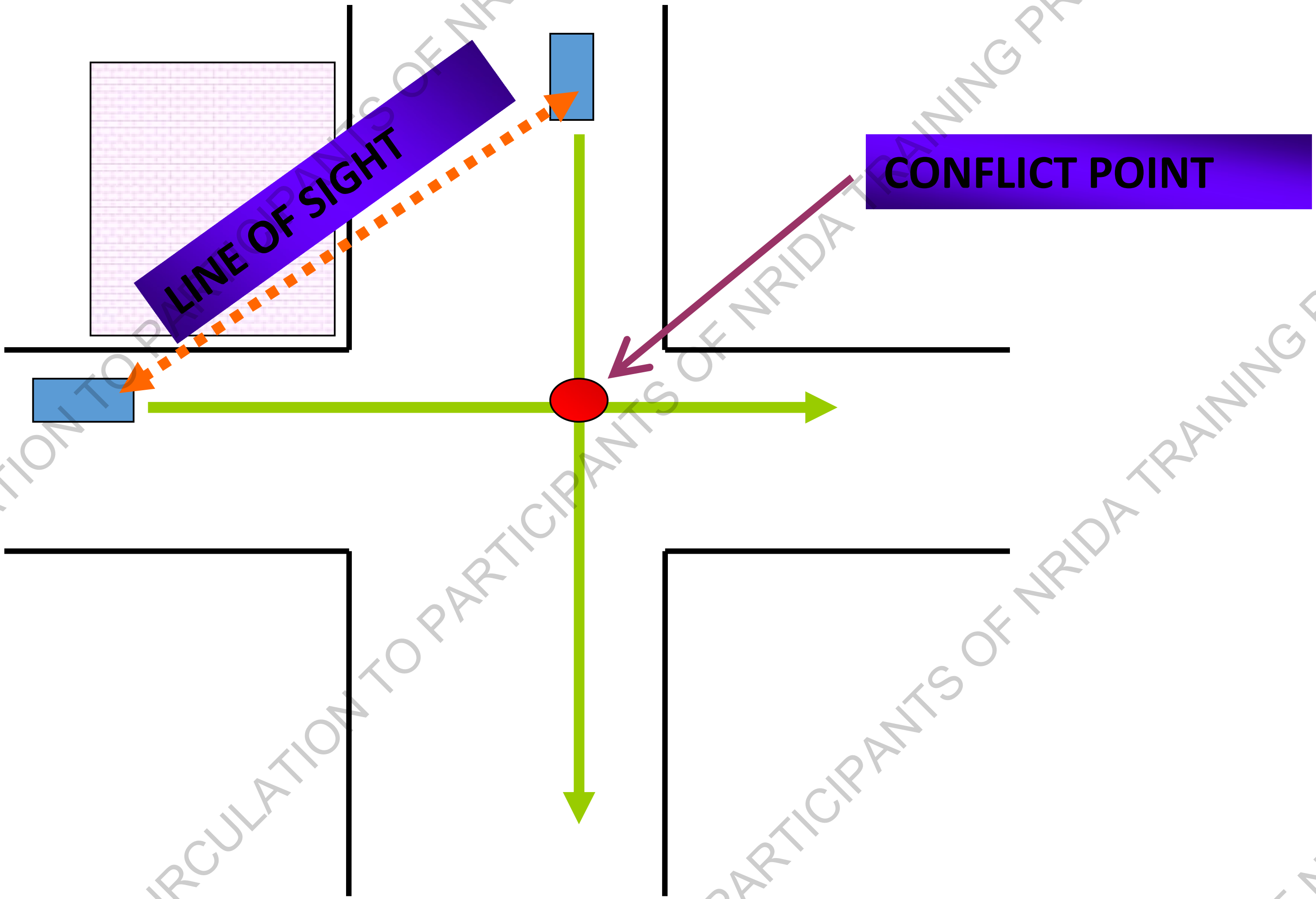
INTERSECTIONS

HORIZONTAL CURVES

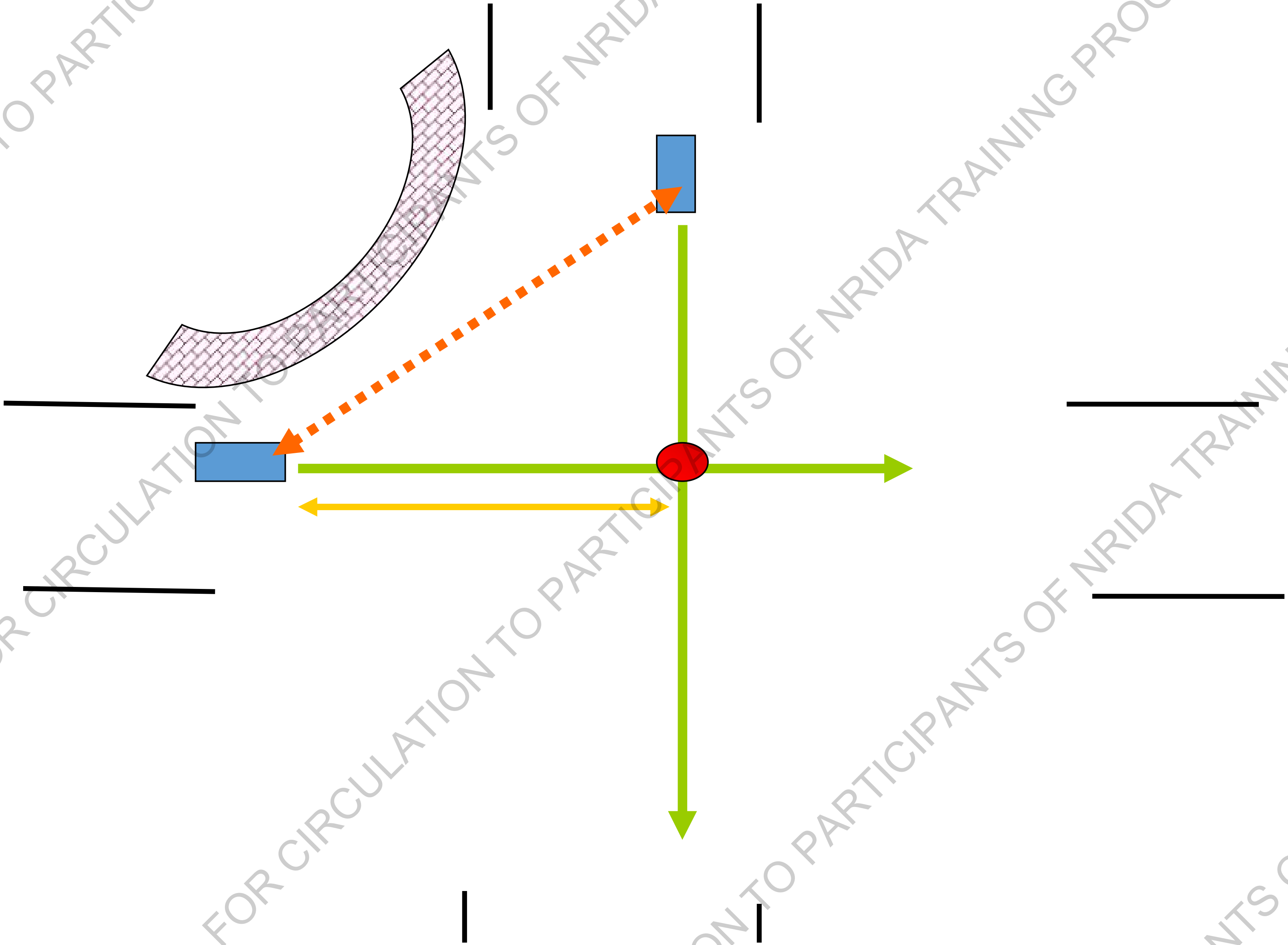
VERTICAL CURVES

SIGNS AND SIGNAL LOCATIONS

INADEQUATE VISIBILITY - BAD INTERSECTION DESIGN



FLARING IMPROVES VISIBILITY



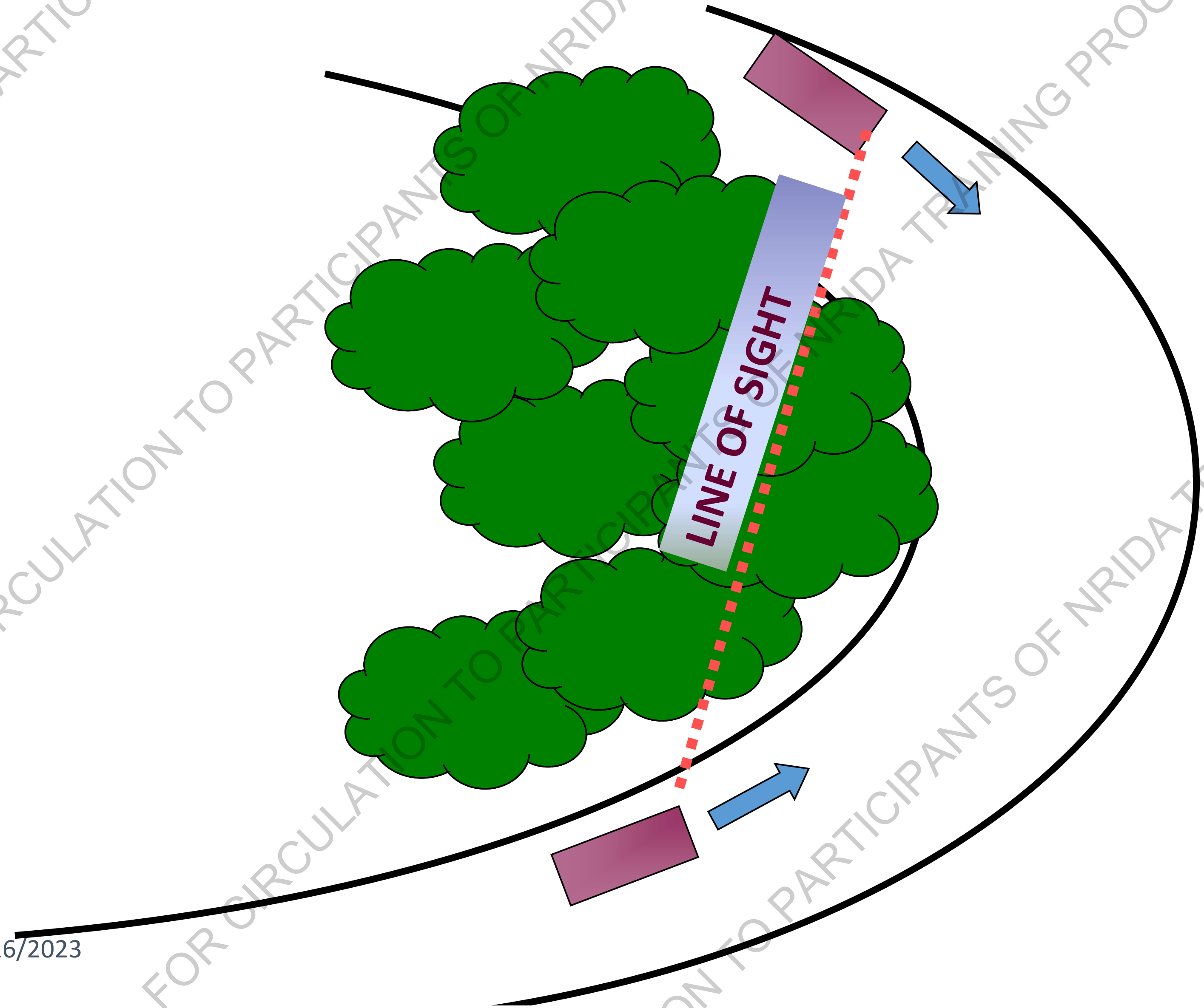
Satellite view of Maroli Circle on Surat-Navsari Highway

Maroli Circle on Surat-Navsari Highway

Street view of Maroli Circle on Surat-Navsari Highway

Street View of T-junction at Sayan Kadrama Road Chainage: 6+300

VEGETATION BLOCKING THE SIGHT ON A HORIZONTAL CURVE



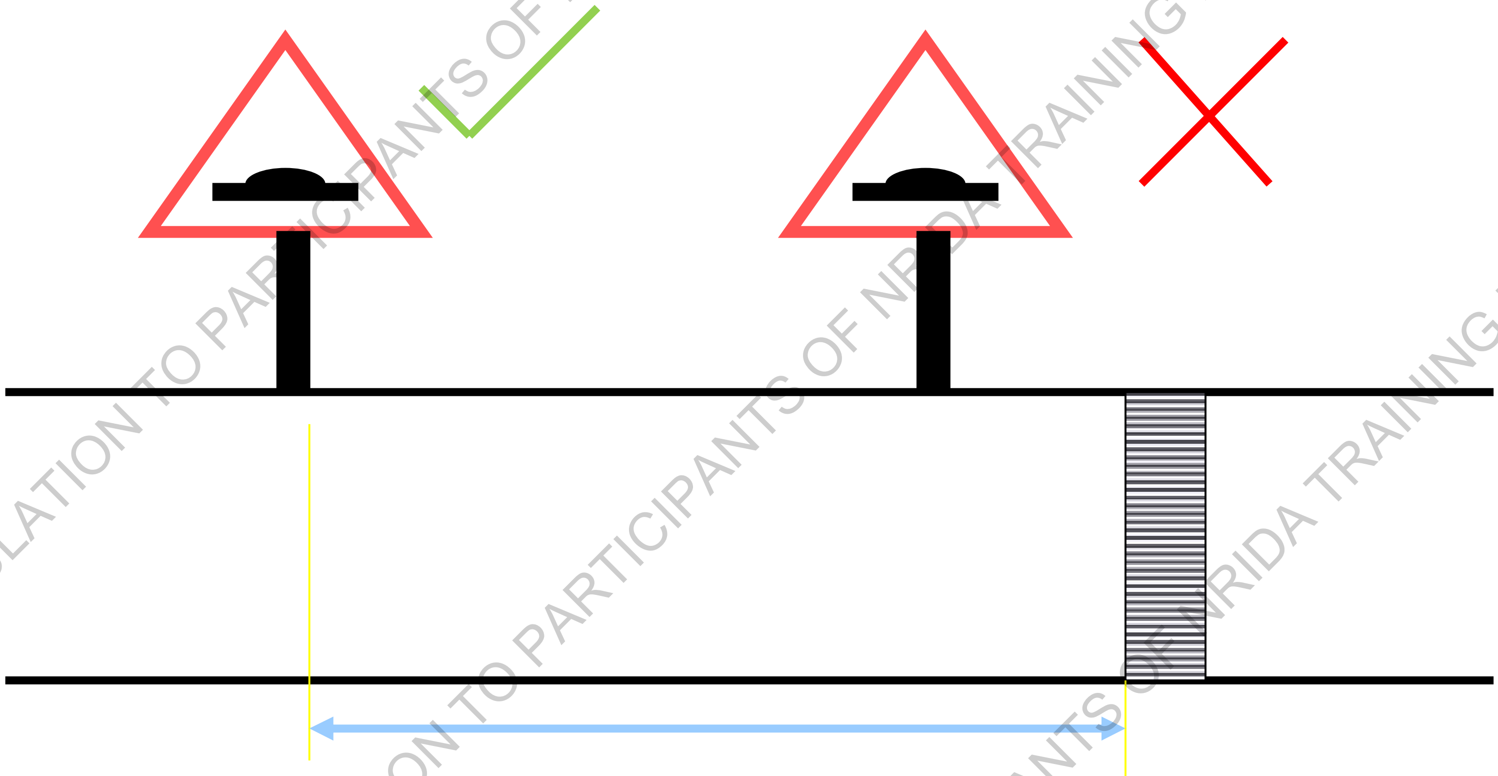
Sharp Horizontal Curve at Ahwa- Chinchli-Babulghat Road (SH-14) Chainage: 1+845-1+928

Satellite View of Sharp Horizontal Curve at Ahwa- Chinchli-Babulghat Road (SH-14) Chainage: 1+845-1+928

Sharp Horizontal Curve at Kharvasa –
Bhatia Road (SH-170) Chainage: 13+380

Sharp Horizontal Curve at Kharvasa – Bhatia Road (SH-170) Chainage: 12+612

Speed Breaker Ahead Sign - Location

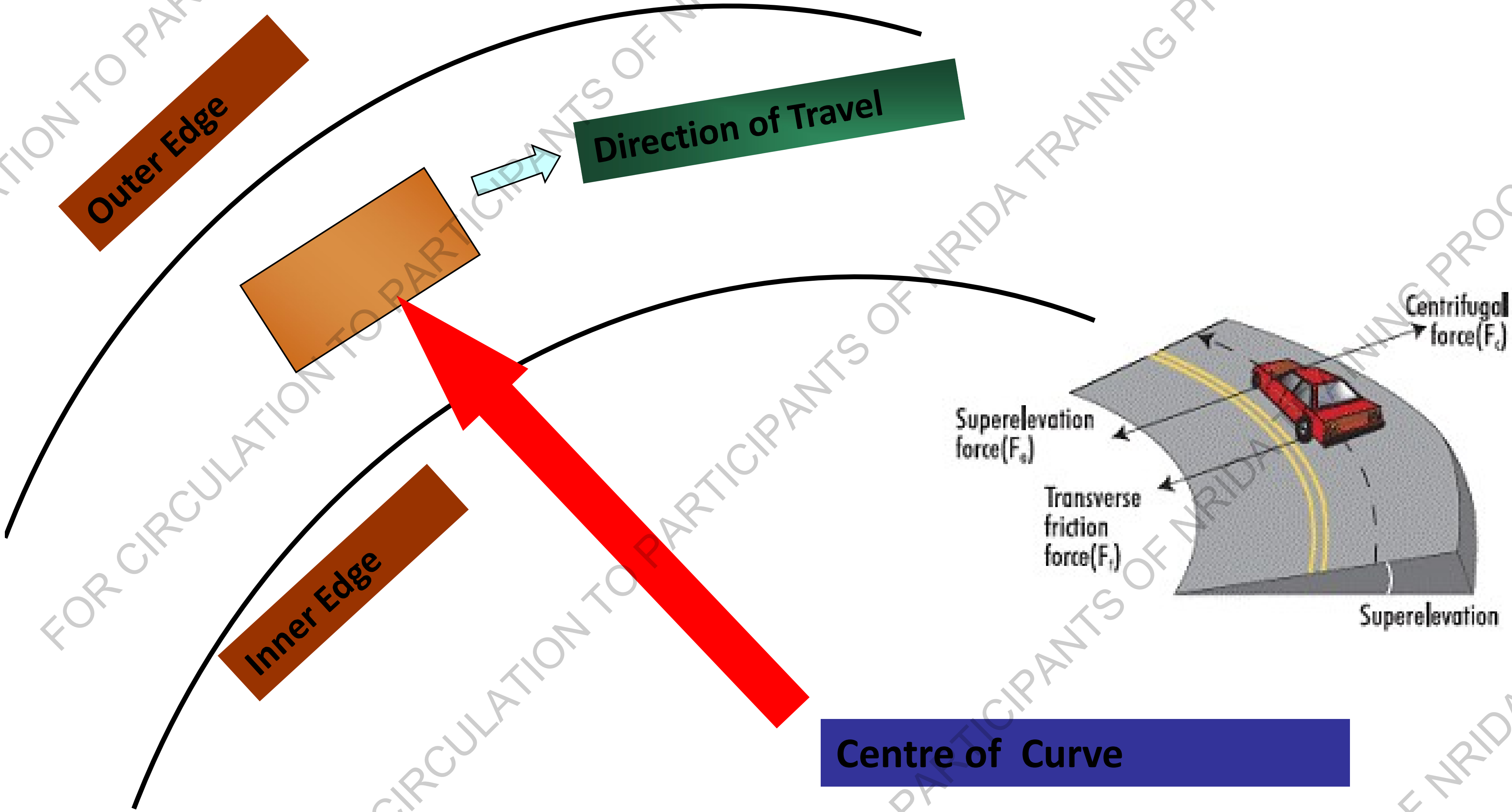


Speed Breaker Sign at Tithal - Dharampur Road (SH-67) Chainage: 3+700 km

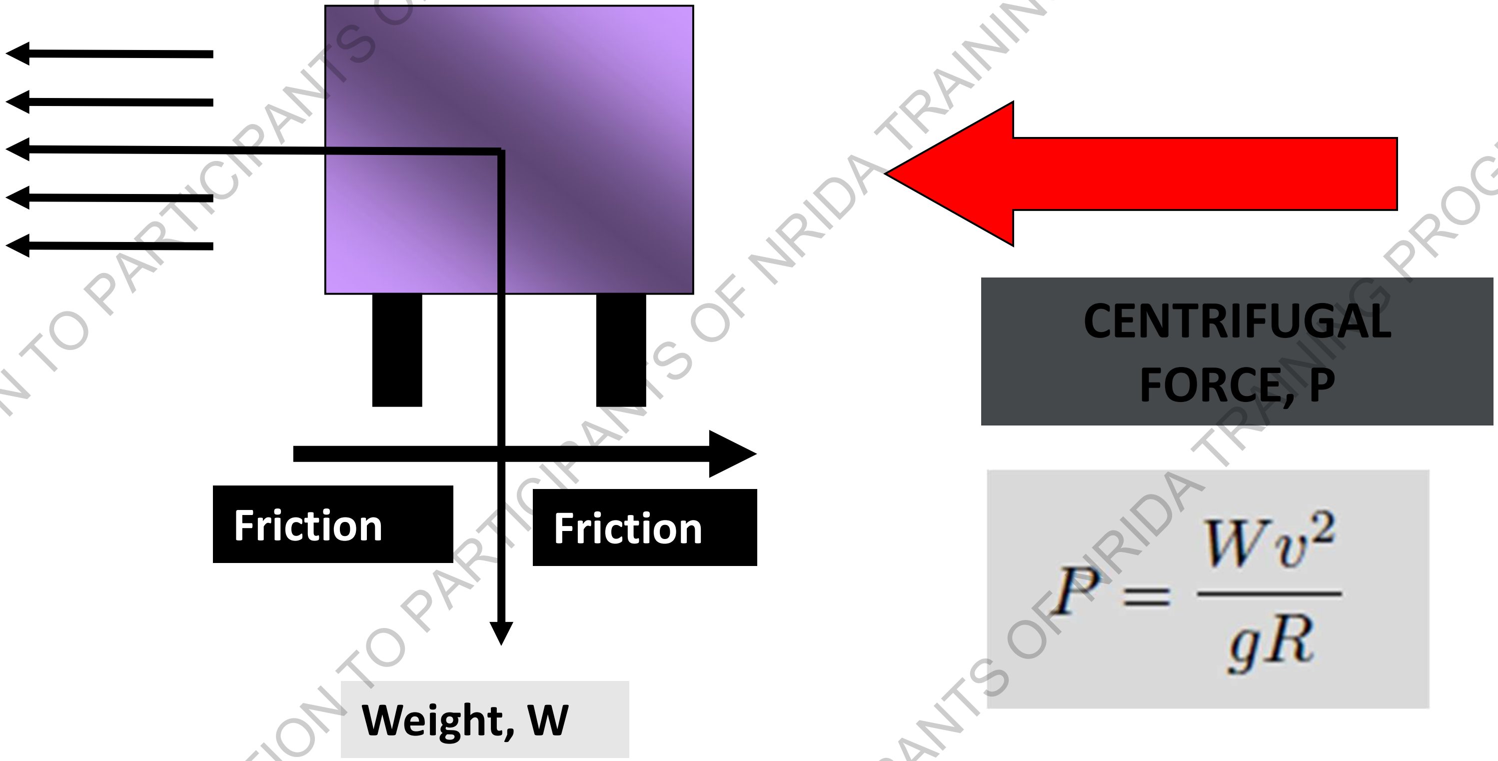
HORIZONTAL ALIGNMENT

- **RADIUS OF CIRCULAR CURVE**
- **SUPER ELEVATION**
- **EXTRA WIDENING**
- **TRANSITION CURVES**

Centrifugal force acting at a curve



Role of friction in resisting skid

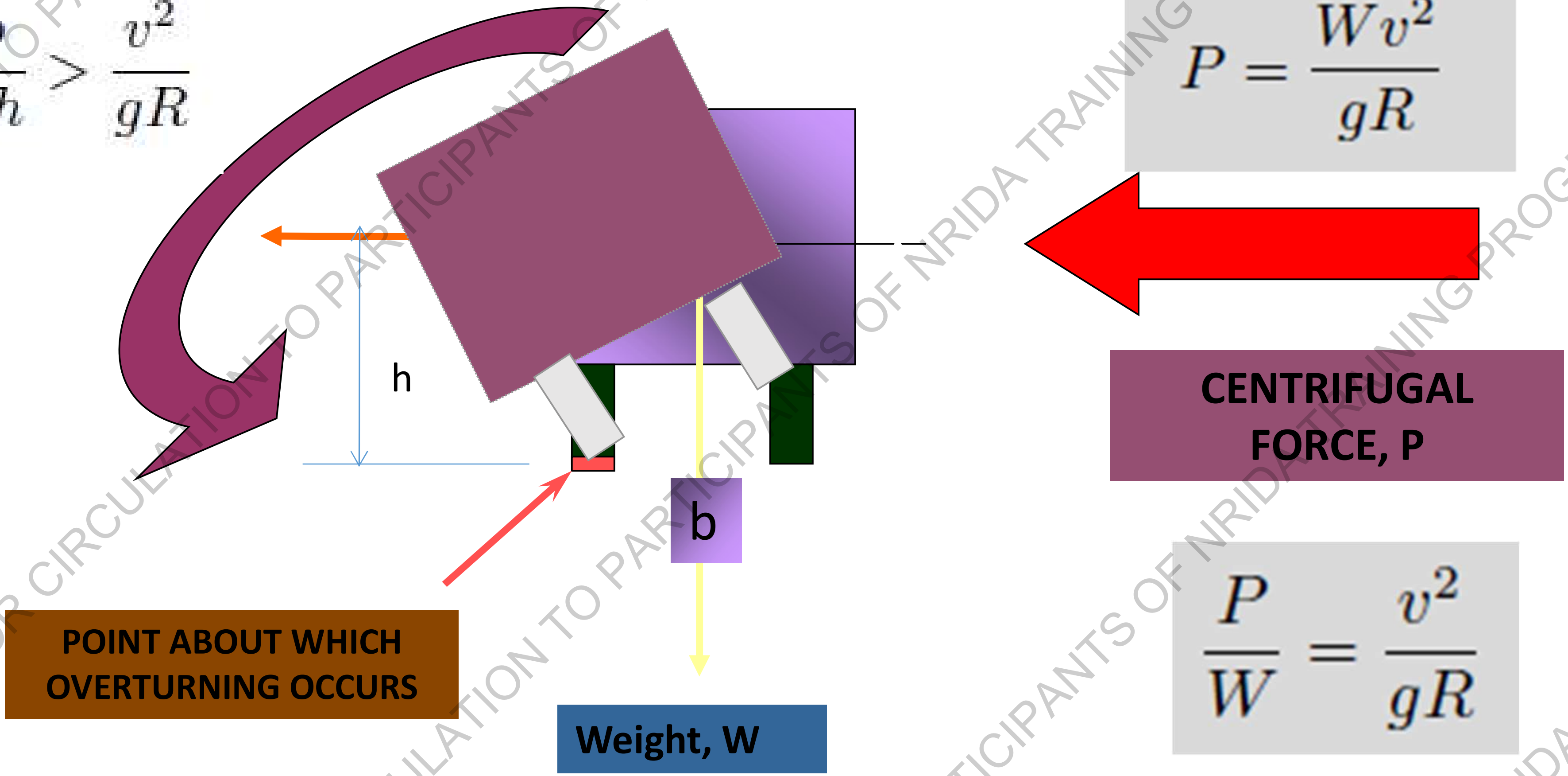


$$P = \frac{Wv^2}{gR}$$

Overturning or toppling

$$\frac{b}{2h} > \frac{v^2}{gR}$$

$$P = \frac{Wv^2}{gR}$$



$$\frac{P}{W} = \frac{v^2}{gR}$$

LIMITING CONDITION, IMPACT FACTOR P/W = b/2h

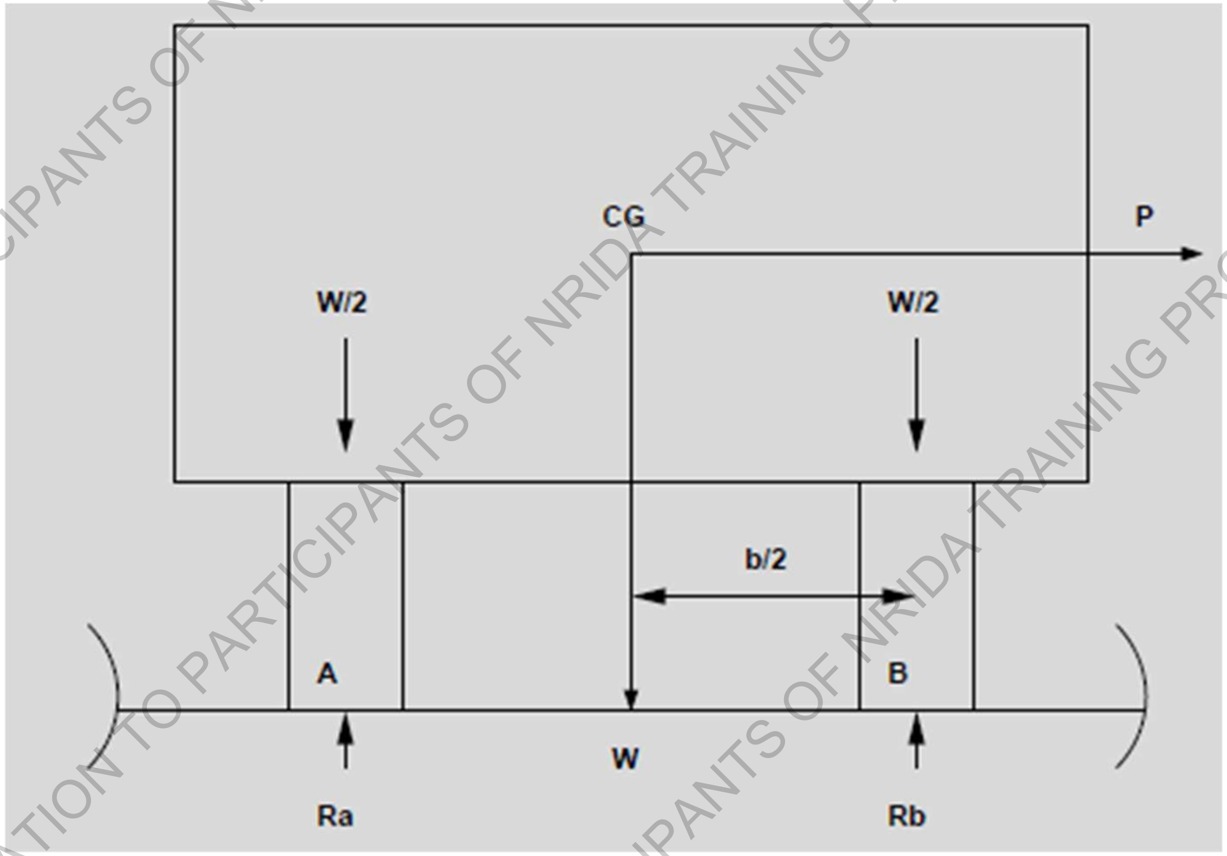
Transverse Skidding

$$F = F_A + F_B$$
$$= f(R_A + R_B)$$
$$= fW$$

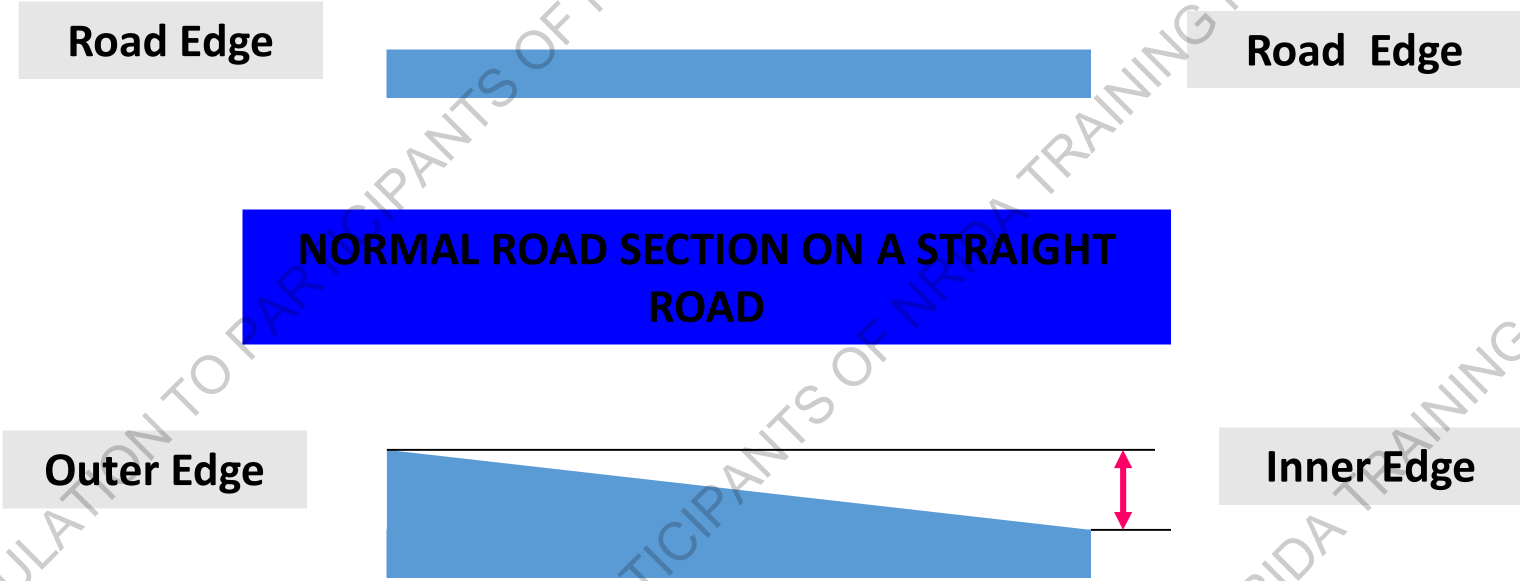
$$P = fW \quad \text{or} \quad \frac{P}{W} = f$$

$$\frac{P}{W} = f = \frac{v^2}{gR}$$

$$f > \frac{v^2}{gR}$$

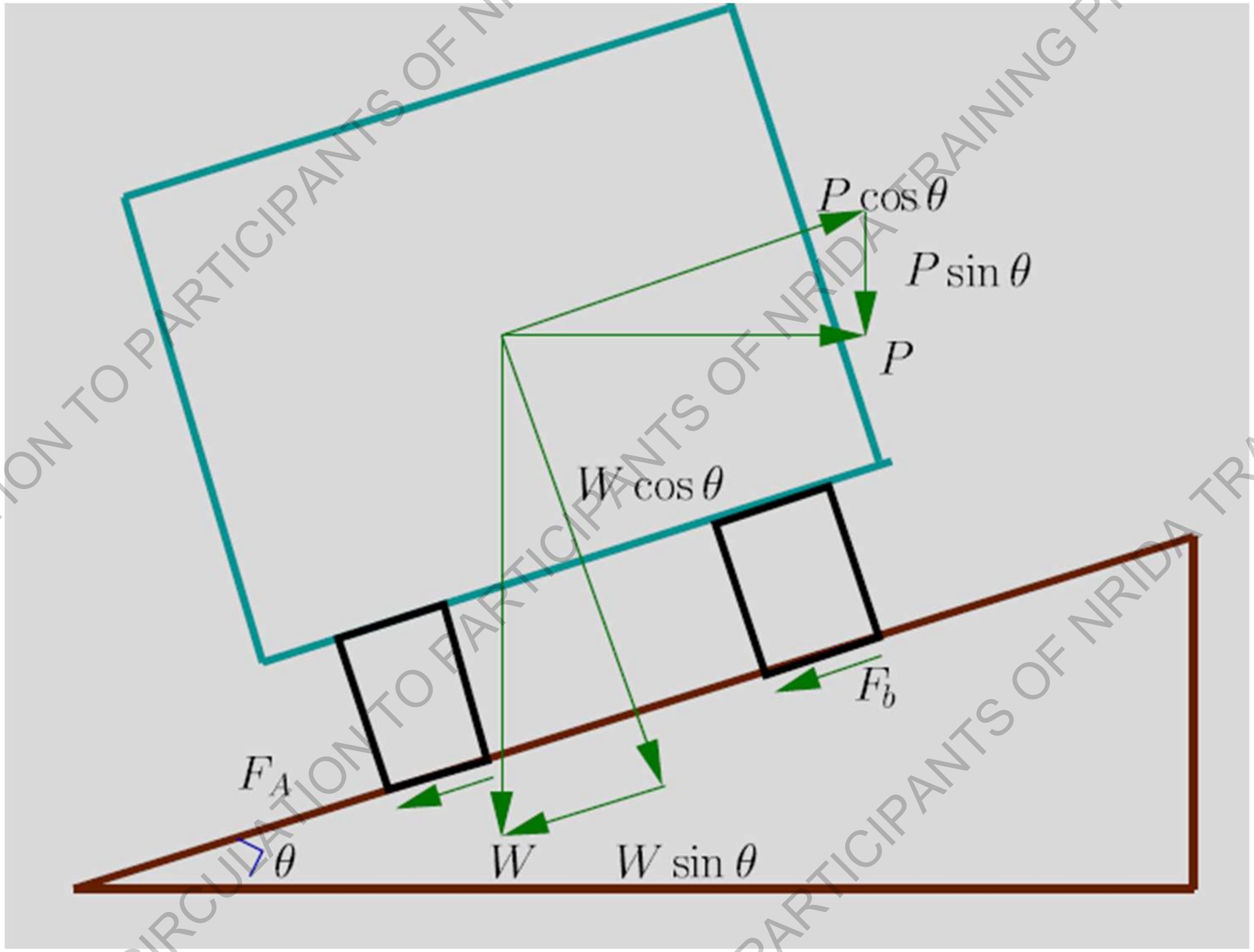


PROVISION OF SUPER ELEVATION



Actual super elevation, E = e B

Analysis of Super elevation



Analysis of Super elevation..

- At equilibrium, by resolving the forces parallel to the surface of pavement we get:

$$\begin{aligned} P\cos\theta &= W\sin\theta + F_A + F_B \\ &= W\sin\theta + f(R_A + R_B) \\ &= W\sin\theta + f(W\cos\theta + P\sin\theta) \end{aligned}$$

- Dividing by Wcosθ we get:

$$\begin{aligned} \frac{P\cos\theta}{W\cos\theta} &= \frac{W\sin\theta}{W\cos\theta} + \frac{fW\cos\theta}{W\cos\theta} + \frac{fPsin\theta}{W\cos\theta} \\ \frac{P}{W} &= \tan\theta + f + f\frac{P}{W}\tan\theta \end{aligned}$$

Analysis of Super elevation..

$$\frac{P}{W}(1 - f\tan\theta) = \tan\theta + f$$

$$\frac{P}{W} = \frac{\tan\theta + f}{1 - f\tan\theta}$$

$$\frac{v^2}{gR} = \frac{\tan\theta + f}{1 - f\tan\theta}$$

This is an exact expression for superelevation
But normally, f = 0:15 and $\theta < 4^o$,
1-f $\tan\theta \sim 1$
and for small θ, $\tan\theta \sim \sin\theta$
E/B = e

Analysis of Super elevation..

- Three specic cases that can arise from equation are as follows:
- If there is no friction due to some practical reasons, then f = 0 and equation becomes $e = \frac{v^2}{gR}$
- This results in the situation where the pressure on the outer and inner wheels are same; requiring very high super-elevation e.
- If there is no super-elevation provided due to some practical reasons, then e = 0 and equation becomes $f = \frac{v^2}{gR}$
- This results in a very high coefficient of friction.
- If e = 0 and f = 0.15 then for safe traveling speed from equation is given by $v_b = \sqrt{fgR}$
- where v_b is the restricted speed.

Analysis of Superelevation..

- If the entire centrifugal force is counteracted by the super-elevation, frictional force will not be called into play (f=0) and the super-elevation then provided is said to be equilibrium super-elevation (pressure on inner and outer wheels will be equal).

<u>Values of coefficient of lateral friction</u>

AASHTO recommends the following values:

Design speed (kmph):	50	65	80	100	120	130
Max. lateral friction:	0.16	0.15	0.14	0.13	0.12	0.11

IRC recommends a constant value of 0.15

Analysis of Super elevation..

- <u>Maximum super-elevation values:</u>

- IRC recommends for hilly areas: 0.07 for snow-bound areas, 0.10 for areas not affected by snow

- All other cases, a value of 0.07 is considered maximum

- <u>Minimum radii of curves:</u>

  $V^2/ 127R = e + f$

  $R = V^2/ 127 (e + f)$

- Knowing e and f, it is possible to calculate the minimum radius

Typical calculations

Minimum Radius of Curve, R = $V^2/127(e + f)$

If V= 50 KMPH, e = 0.07, f = 0.15

R = 89 m, say 90 m

Design of super elevation

Design of super elevation for mixed traffic conditions is complex and thus the following steps are followed:

(i) Super elevation for 75% of design speed is calculated neglecting the friction

$$e = (.75V)^2 / 127R = V^2 / 225R$$

(ii) If calculated 'e' value is less than 0.07, the value thus obtained is provided. If the value exceeds 0.07, provide maximum super elevation of 0.07.

(iii) Check the coefficient of friction developed for maximum value of 'e'

$$f = (V^2 / 127R - 0.07)$$

Design of super elevation…

If the value thus obtained is less than 0.15, superelevation of 0.07 is safe for design.

Alternatively:

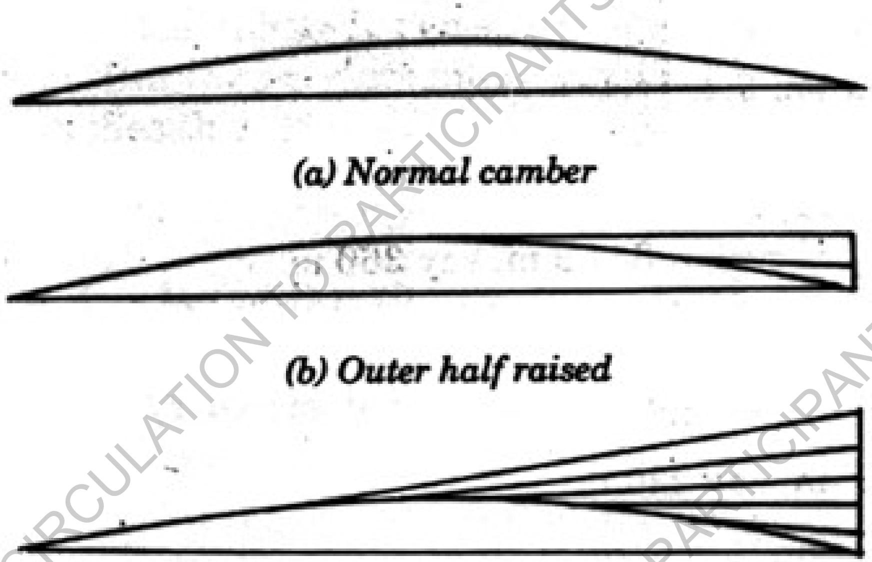
$e + f = 0.07 + 0.15 = 0.22 = V_a^2 / 127R$

Calculate safe allowable speed V_a

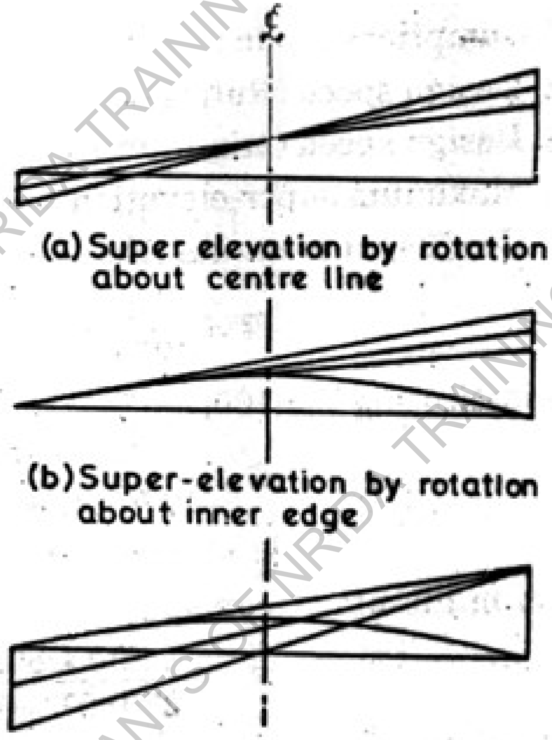
If the allowable speed is higher than the design speed, then design is adequate and provide "e" equal to 0.07

If speed is less than the design speed, "speed limit" is to be introduced.

Attainment of Super elevation



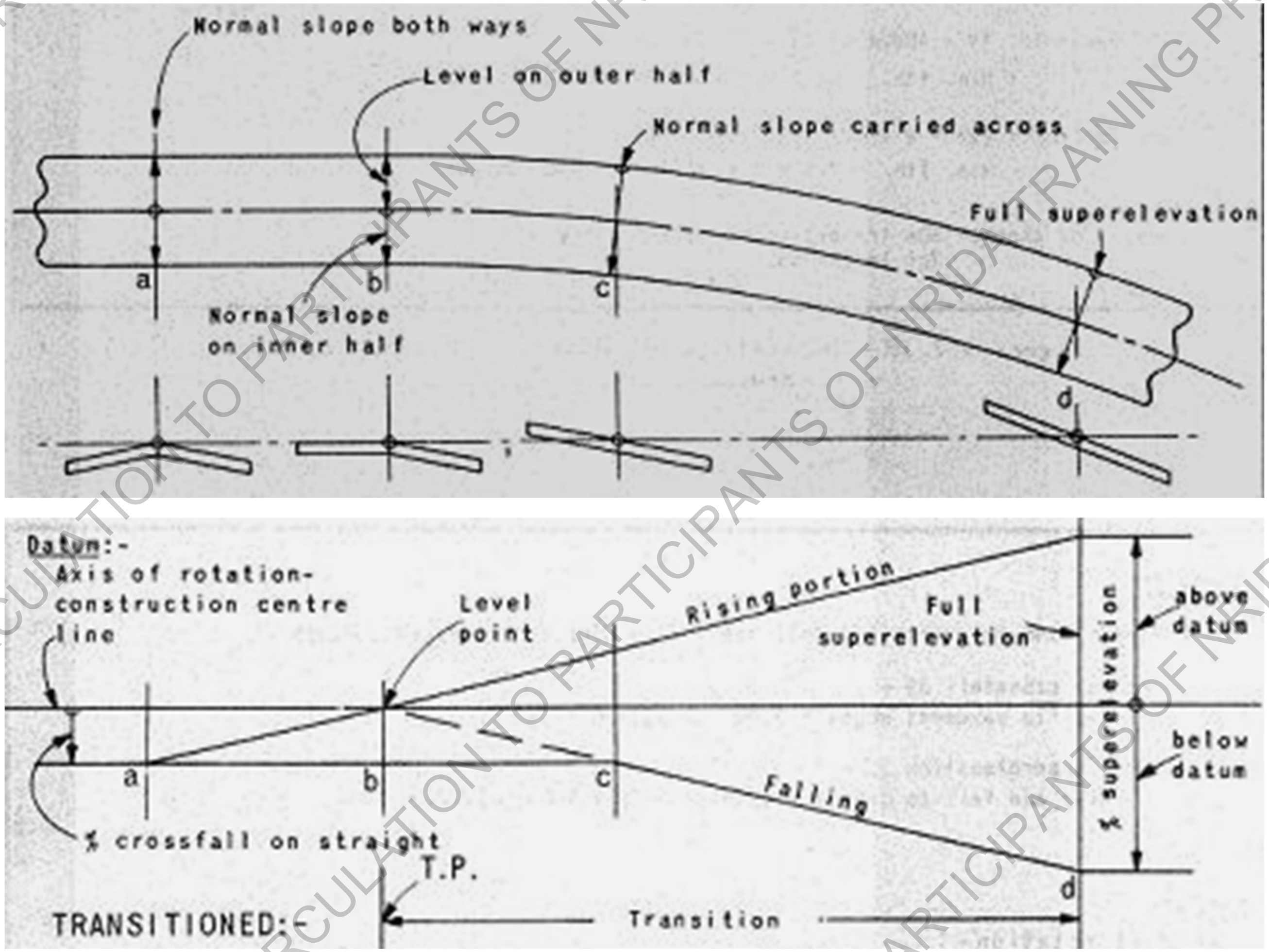
(c) Super elevation equal to camber
Fig. 6.5. First stage in attaining super-elevation equal to camber.



(c) Super elevation by rotation about outer edge

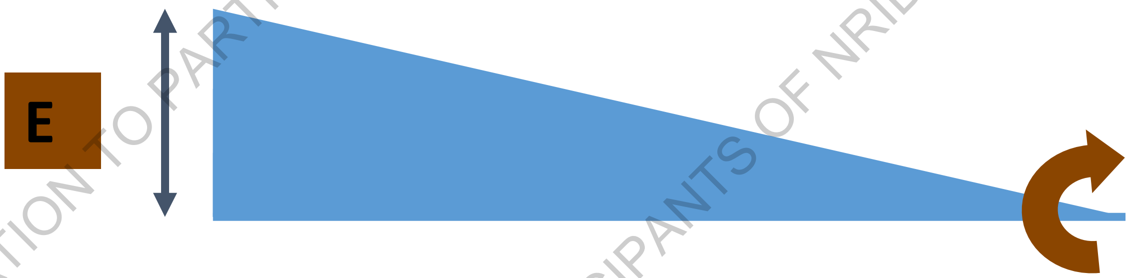
ig. 6.6. Second stage in attaining super-elevation.

Attainment of Super elevation…



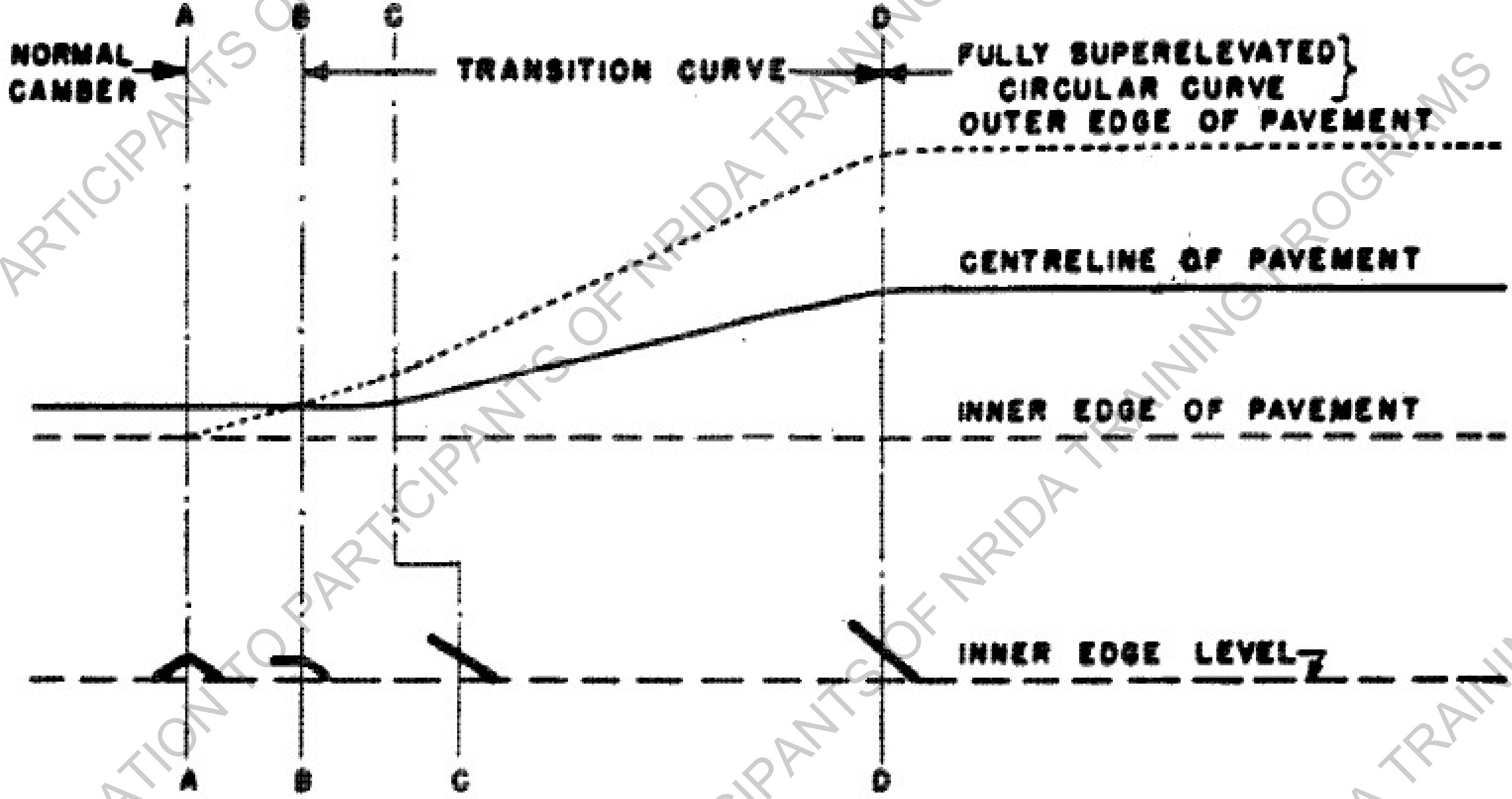
METHODS OF ATTAINING SUPERELEVETION

1. **Rotating the pavement with respect to inner edge**



If the rate of introduction of super elevation is 1 in N , required length = N.E

Preferred in flat terrain in high rainfall area, when the road is not taken into embankment to avoid the drainage problem.



(b) PAVEMENT REVOLVED ABOUT INNER EDGE

Vertical Profile

LEGEND

CROSS SECTION AT AA–NORMAL CAMBER

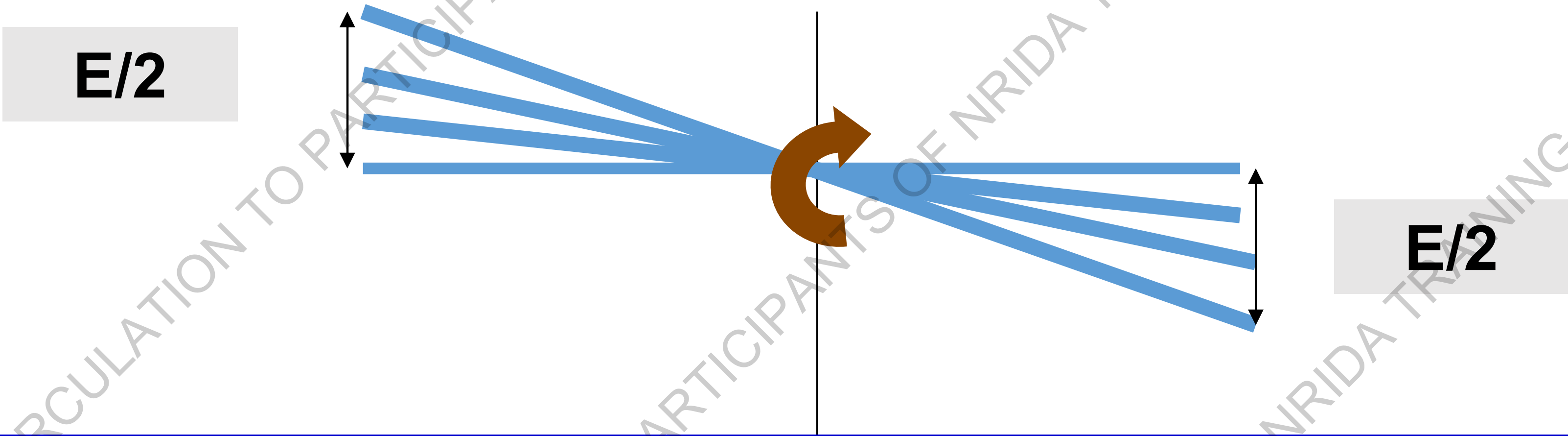
CROSS SECTION AT BB–ADVERSE CAMBER REMOVED

CROSS SECTION AT CC–SUPERELEVATION EQUAL TO CAMBER

CROSS SECTION AT DD–FULL SUPERELEVATION ACHIEVED

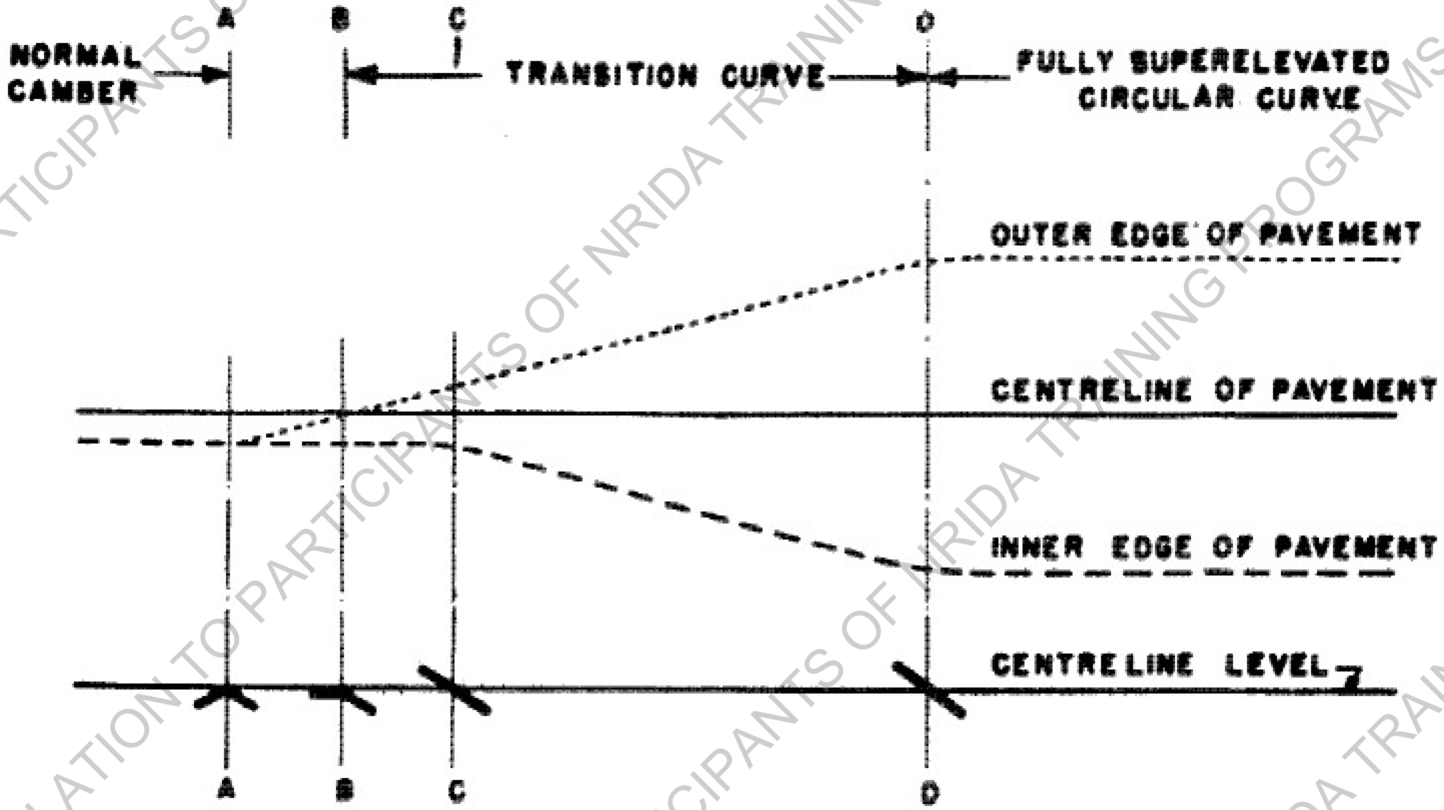
METHODS OF ATTAINING SUPERELEVETION

2. Rotating the pavement with respect to centre line



If the rate of introduction of super elevation is 1 in N , required length = N.E / 2

Preferred when the road has significant gradient, when the road is taken into embankment to avoid the drainage problem.



(a) PAVEMENT REVOLVED ABOUT CENTRELINE

Vertical Profile

LEGEND

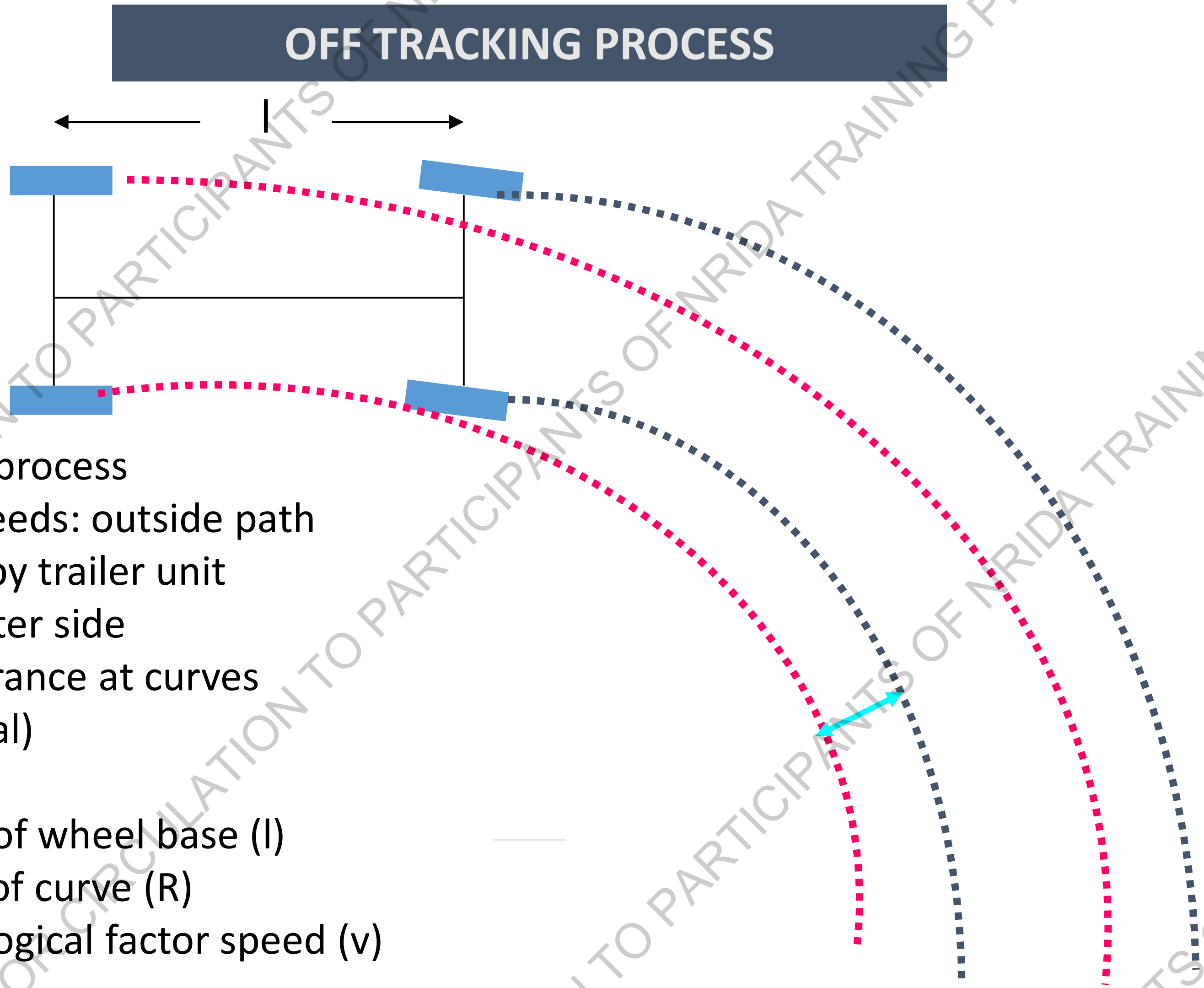
CROSS SECTION AT AA–NORMAL CAMBER

CROSS SECTION AT BB–ADVERSE CAMBER REMOVED

CROSS SECTION AT CC–SUPERELEVATION EQUAL TO CAMBER

CROSS SECTION AT DD–FULL SUPERELEVATION ACHIEVED

EXTRA WIDENING ON CURVES

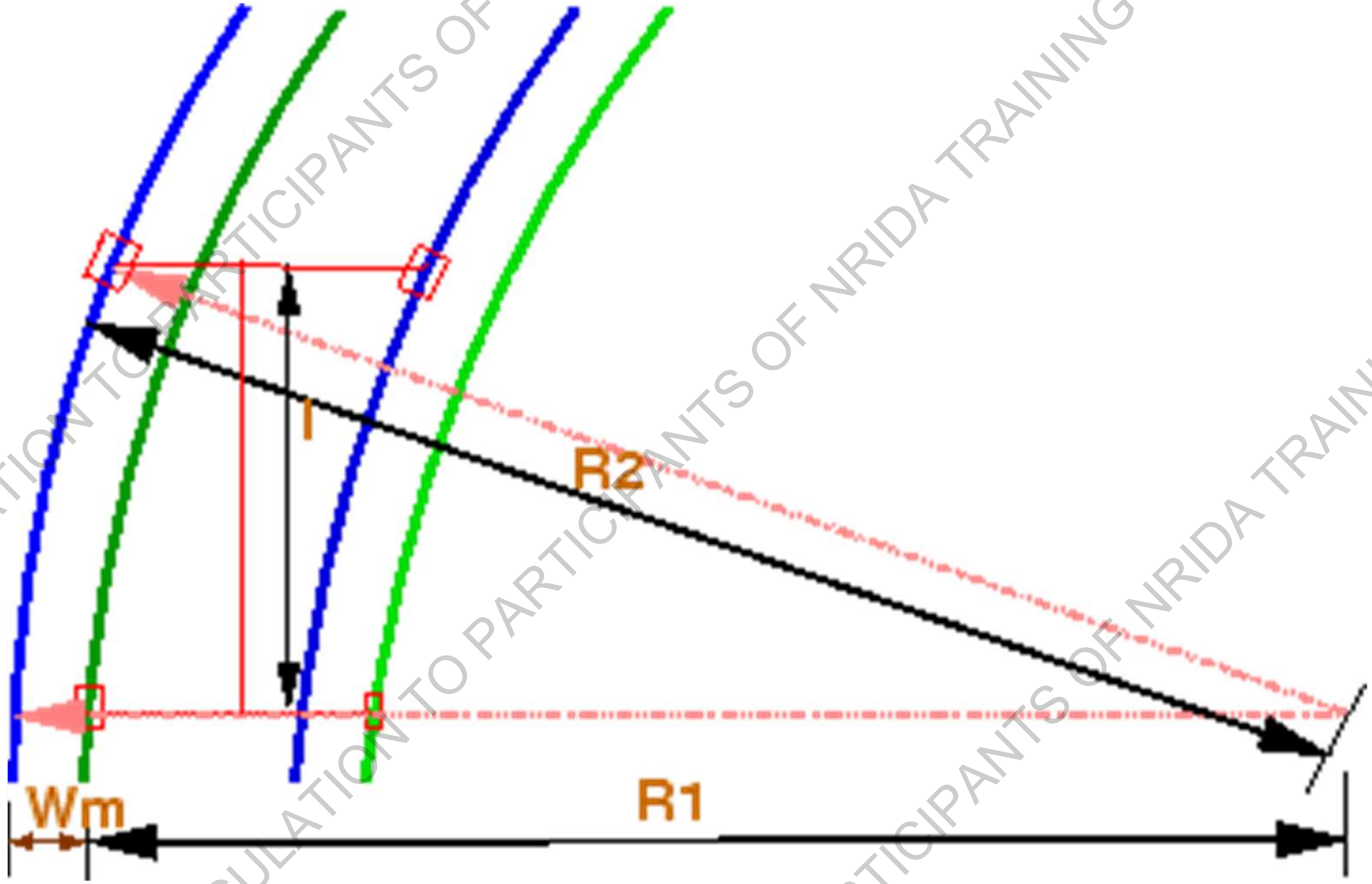


1. Off-tracking process
2. At higher speeds: outside path
3. Path traced by trailer unit
4. At curves outer side
5. Greater clearance at curves (psychological)
6. Factors
   1. Length of wheel base (l)
   2. Radius of curve (R)
   3. Psychological factor speed (v)

EXTRA WIDENING ON CURVES : Examples

Photo: Dan Nabors, VHB

Widening of Pavement on Horizontal Curves



Widening of Pavement on Horizontal Curves

$W_m = OC - OA = OB - OA = R_2 - R_1$

$OA^2 = OB^2 - BA^2$

$R_1^2 = R_2^2 - l^2$

But $R_1 = R_2 - w_m$

Thus $w_m = l^2 / (2R_2 - w_m) = l^2 / 2R$ (approx.)

For, n number of lanes, widening is: $n \times w_m$

As per IRC:

Psychological widening, $W_{ps} = 0.1 V / \sqrt{R}$

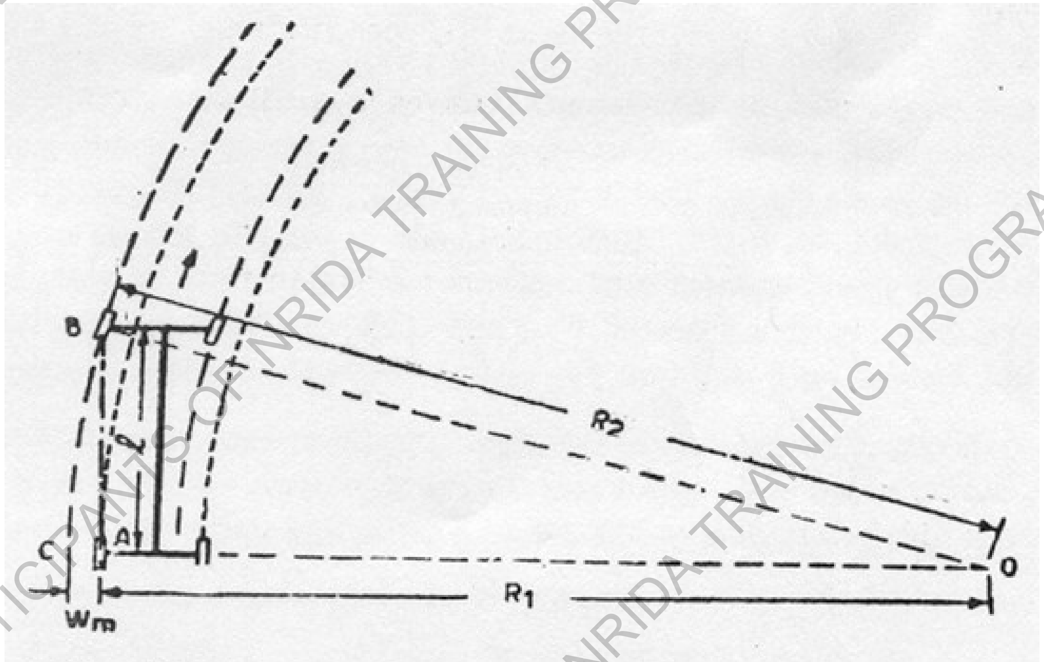
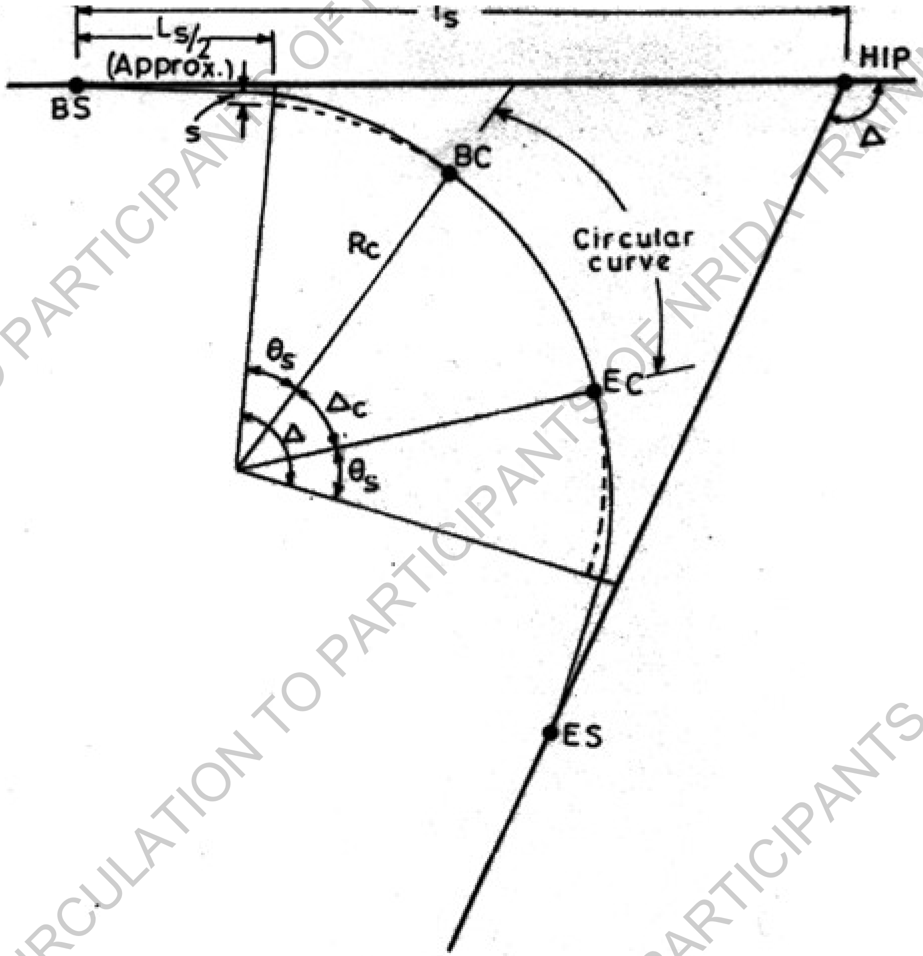


Fig. 4.25 Mechanical Widening on Horizontal Curve

Transition curves

- When a vehicle travelling on a straight course enters a curve of finite radius, it is subjected to centrifugal force which causes discomfort to the passengers.
- To avoid, it is customary to provide transition curve at the beginning of circular curve.
- Transition curves have radius of infinity at the end of straight stretch, which gradually reduces to be equal to the radius of the circular curve (where it begins)
- Transition portion is also used for the gradual application of super-elevation and extra widening of pavement.

IRC recommends spiral



Length of transition curve

Three considerations:

(1) Rate of change of centrifugal acceleration should not cause discomfort to drivers and passengers. If C is the rate of change of acceleration,

$C = v^2 / R_c / t = (v^2/R_c)/(L_s/v) = v^3 / R_c L_s$

Thus $Ls = 0.0215\, V^3 / CR_c$, where V is speed in kmph

According to IRC, $C = 80/(75 + V)$ m/sec^3 [$0.5<C<0.8$]

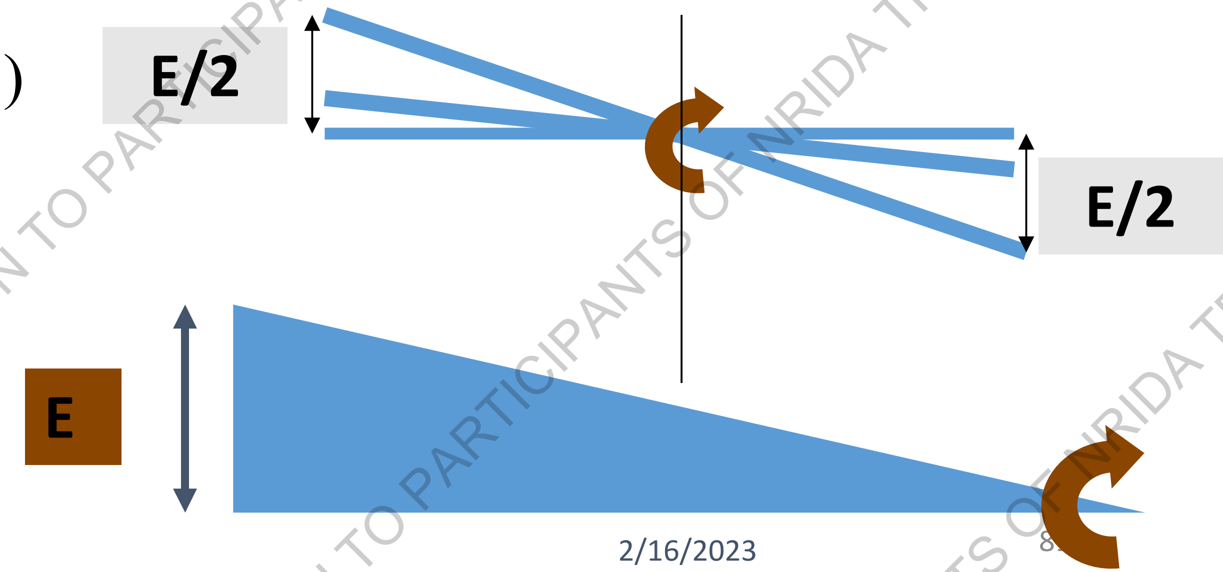
Minimum and maximum values are 0.5 and 0.8 respectively

Length of transition curve

(2) Rate of change of super-elevation should be such as not to cause higher gradients and unsightly appearances. This may be kept at 1 in 150 for roads in plain and rolling terrain and 1 in 60 for roads in hilly terrain, 1 in 100 for roads in built up areas.

$$Ls = \frac{E * N}{2} = \frac{eN}{2}(W + W_e)$$

$$Ls = E * N = eN(W + W_e)$$



Length of transition curve

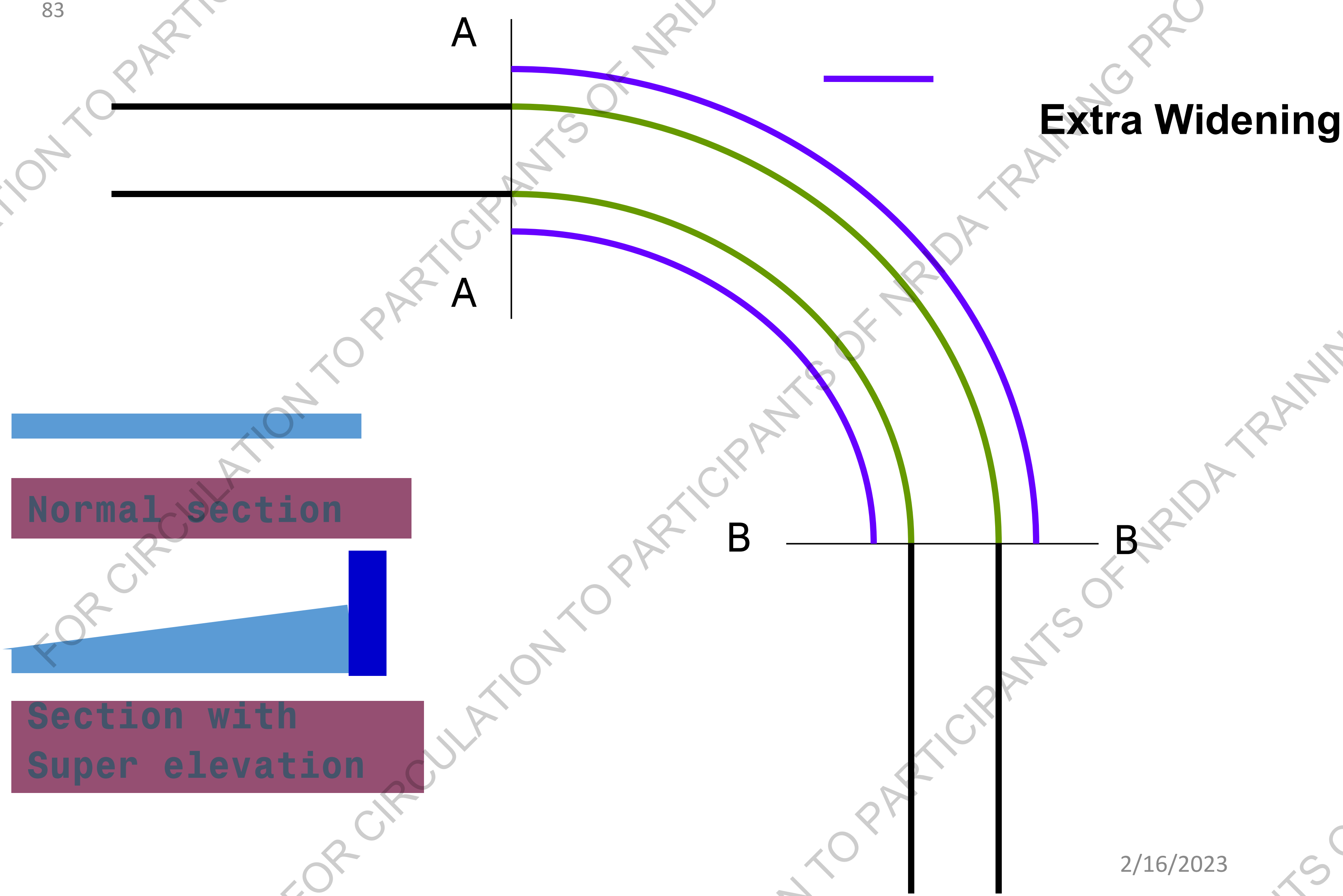
- By empirical formula
- Case 1: For plain and rolling terrain

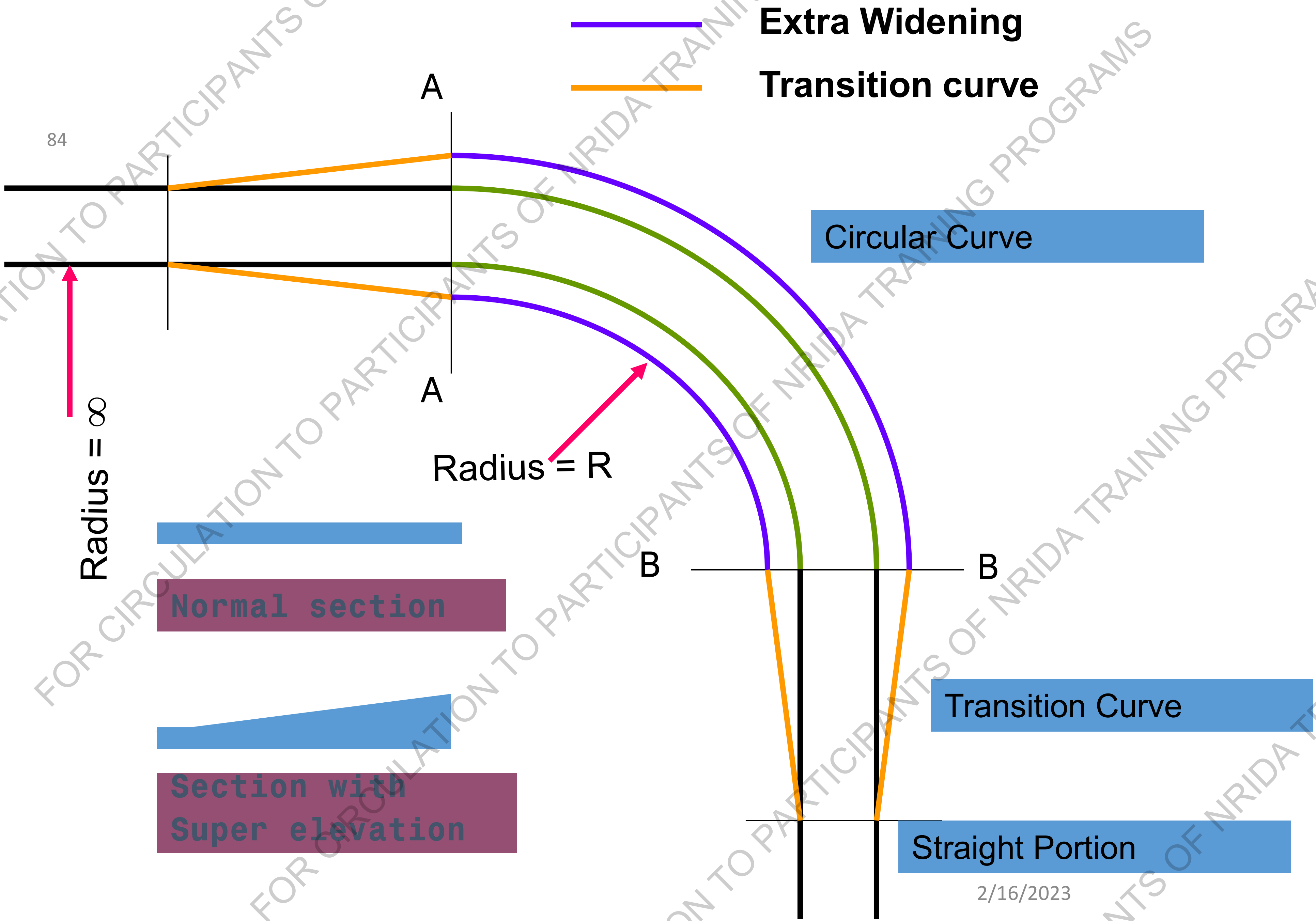
$$L_s = \frac{2.7V^2}{R}$$

- Case 2: For mountainous and steep terrain

$$L_s = \frac{V^2}{R}$$

NEED FOR A TRANSITION CURVE




Extra Widening
Transition curve
A
A
Circular Curve
Radius = ∞
Radius = R
B
B
Normal section
Section with
Super elevation
Transition Curve
Straight Portion

IRC Recommendations

IRC specifications for extra widening:

Table 18. Extra width of pavement at horizontal curves(IRC: 73-1980)

Radius (m)	Upto 20	21-40	41-60	61-100	101-300
Extra width (m)					
two-lane road	1.5	1.5	1.2	0.9	0.6
One lane	0.9	0.6	0.6	nil	nil

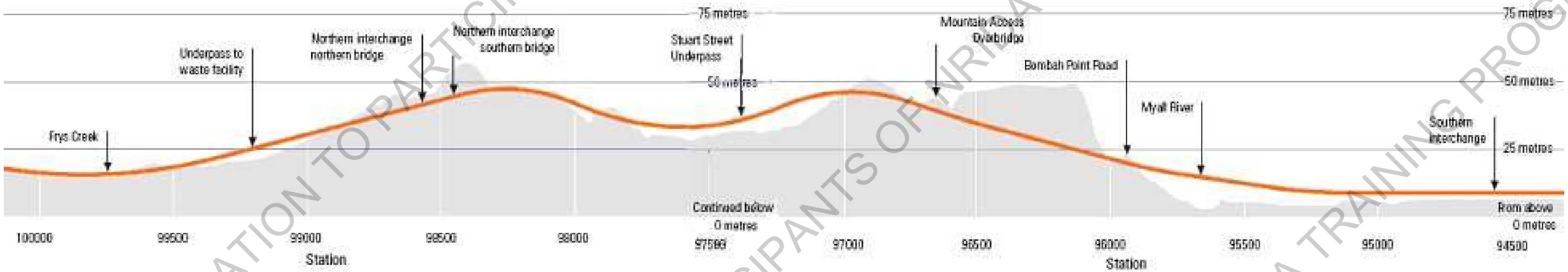
VERTICAL ALIGNMENT

GRADIENTS

SUMMIT CURVES

VALLEY CURVES

Vertical Profile and central line of the road



Gradients

Gradient is decided for designing the vertical curve.

- *Ruling gradient* is the maximum gradient within which to design the vertical profile of a road. Cut and fill are balanced accordingly. (Design Gradient)
- Flatter gradients may be preferred
- Selection of ruling gradient depends on type of terrain, length of grade, speed, power of vehicle, horizontal curves.
- Vehicle with the same tractive effort would lose speed at grades; speed would steadily decrease with increase in length
- With maximum pulling power, a vehicle would be able to sustain the same speed even on long section only up to a certain gradient

Gradients..

- Maximum power developed by the engine is equal to the power required to overcome the resistance to motion on the grade at a speed is the ruling gradient for the vehicle.
- Different kind of vehicles use the road
- IRC recommendations:
  - 1 in 30 on plain and rolling terrain
  - 1 in 20 on mountainous terrain
  - 1 in 16.7 on steep terrain
- Topography of a place compels adopting steeper gradients known as *limiting gradient.* Length should be restricted and must be provided after a gap.

Gradients..

- In some extra-ordinary situations, it may become unavoidable to provide still steeper gradient, known as *exceptional gradient.*
- Should be strictly limited to short stretches, not exceeding 100m at a stretch.
- Maximum length of ascending gradient which a loaded truck can operate without undue reduction in speed is called *critical length of grade*. (A reduction of speed of 25kmph may be considered reasonable).
- For a flat terrain gradient needs to be provided for drainage purposes.
- 1 in 500 may be sufficient for concrete drains; for inferior surfaces I in 200 is desirable

Gradients…

Table 1. Gradients for Roads in Different Terrains (IRC SP 23-1983)

	Ruling	Limiting	Exceptional
Plain and rolling:	1 in 30	1 in 20	1 in 15*
Rolling	1 in 30	1 in 20	1 in 15*
Mountainous	1 in 20	1 in 16.7	1 in 14.3*
Steep			
i. Up to 3000m above MSL			
	1 in 20	1 in 16.7	1 in 14.3*
ii. Above 3000m above MSL			
	1 in 16.7	1 in 14.3	1 in 12.5*

* For a distance not more than 100m at a stretch

Vertical Curves

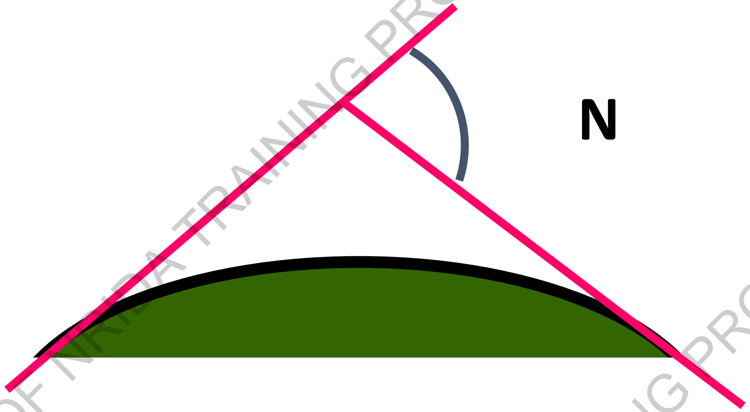
- Vertical curves are provided:
  - Gradual transition from one gradient to another without discomfort to passengers
  - Eliminate sudden humps and troughs
  - Adequate visibility for stopping and overtaking

- If the total change in gradient from one tangent to another does not exceed 0.5%, vertical curves can be dispensed with

- Parabola is usually used for joining two tangents

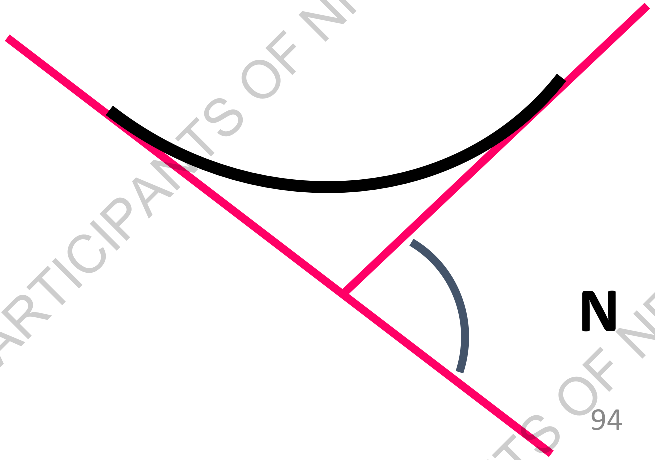
Types of vertical curves

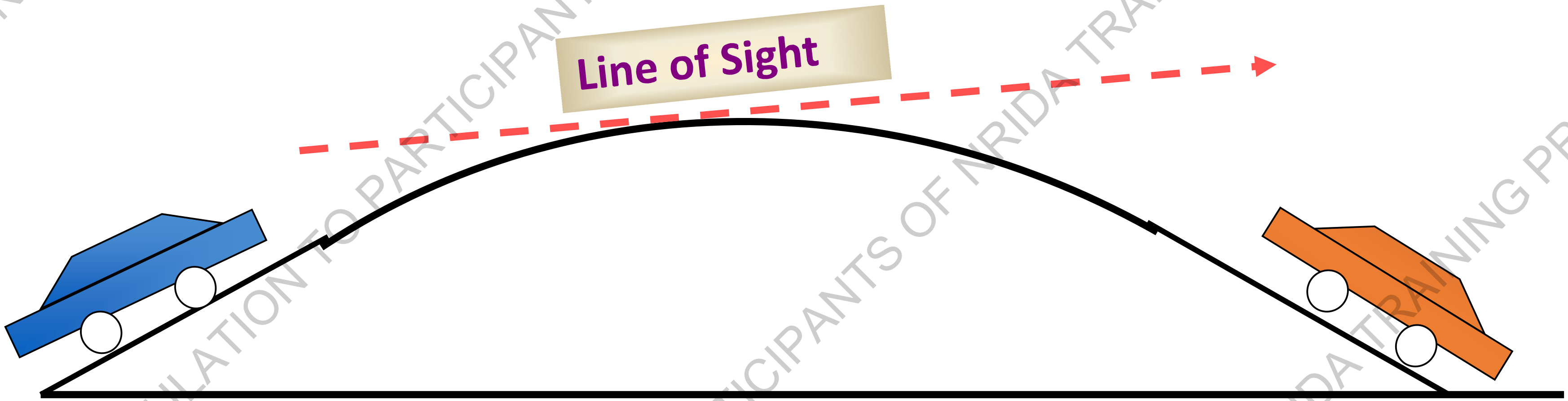
- SUMMIT CURVE OR CREST CURVE



N = ANGLE OF DEVIATION

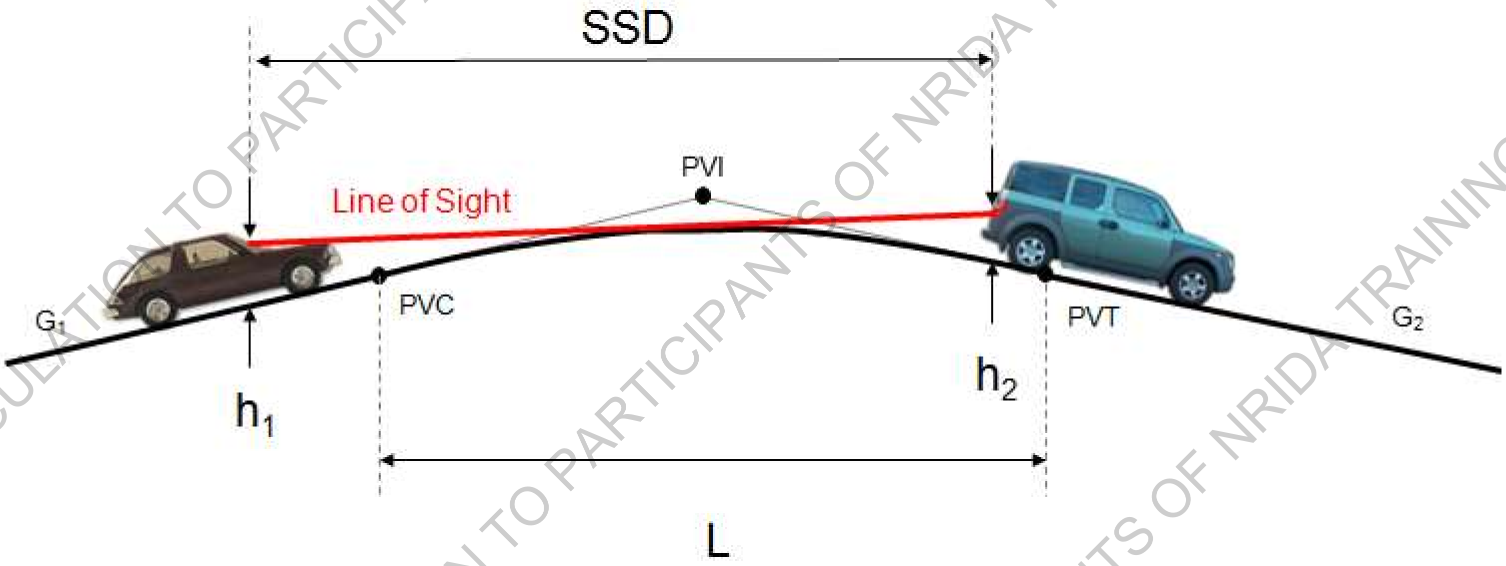
- VALLEY CURVE OR SAG CURVE





SIGHT DISTANCES AT VERTICAL CURVES ARE AFFECTED BY GRADIENT. FLATTER SLOPES PROVIDE HIGHER VISIBILITY

Street View of Vertical Curve-4 at Ahwa- Chinchli-Babulghat Road (SH-14) chainage 10+668


SSD
PVI
Line of Sight
PVC
PVT
G_1
G_2
h_1
h_2
L

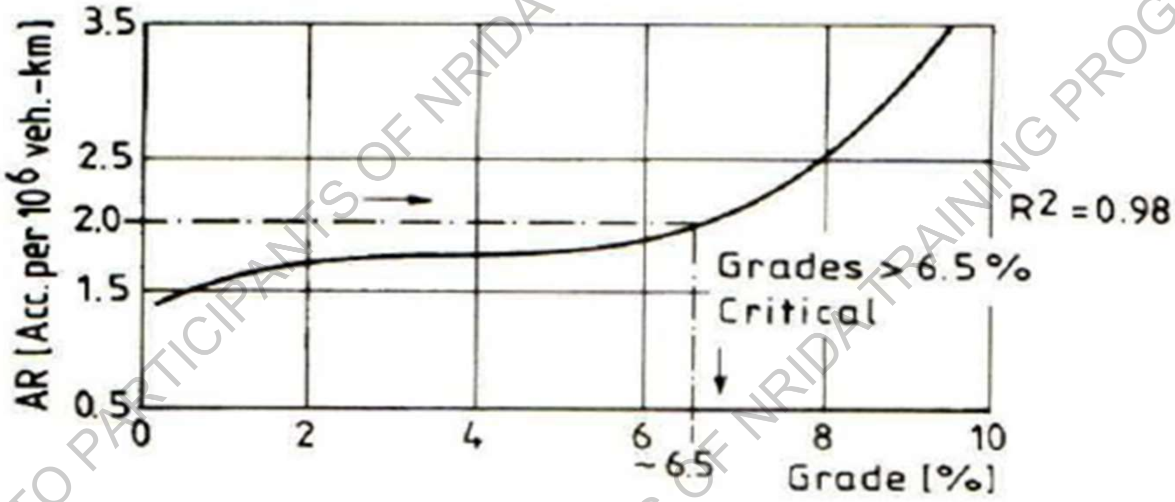
Accident rate (AR) Vs Gradient of vertical curve

Sudden increase in the accident rate on gradient beyond 6.5 %

Source:-

Technical University of Istanbul, Turkey

1997



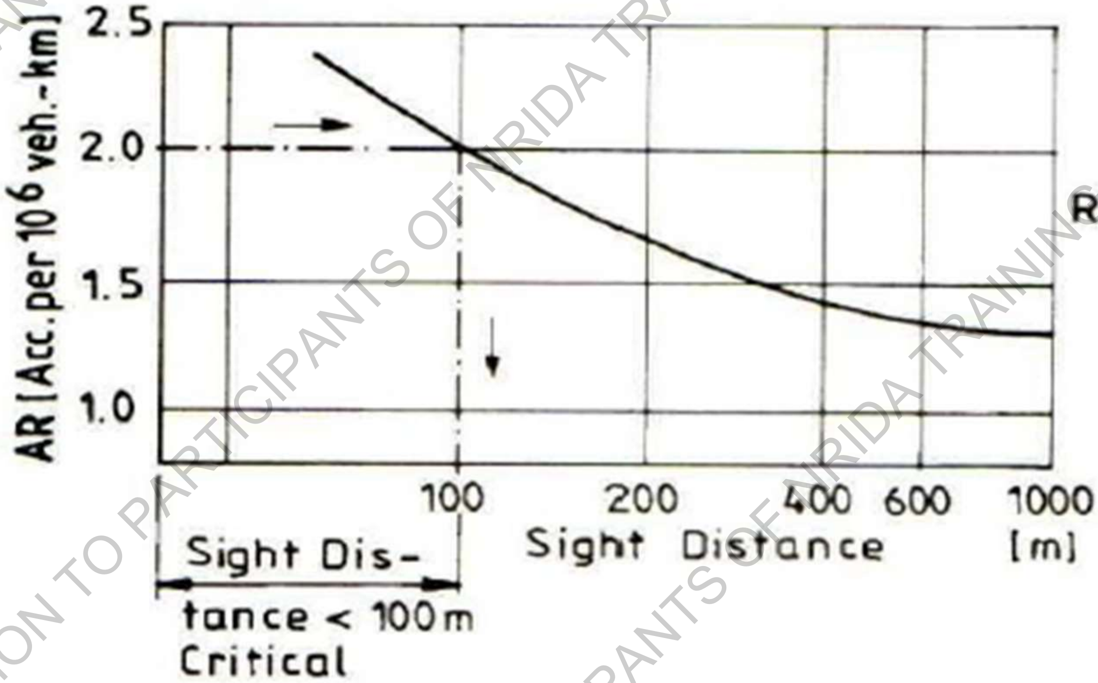
Accident rate (AR) Vs Sight distance at vertical curves

Critical sight distance is 100 m.

Source:-

Technical University of Istanbul, Turkey

1997



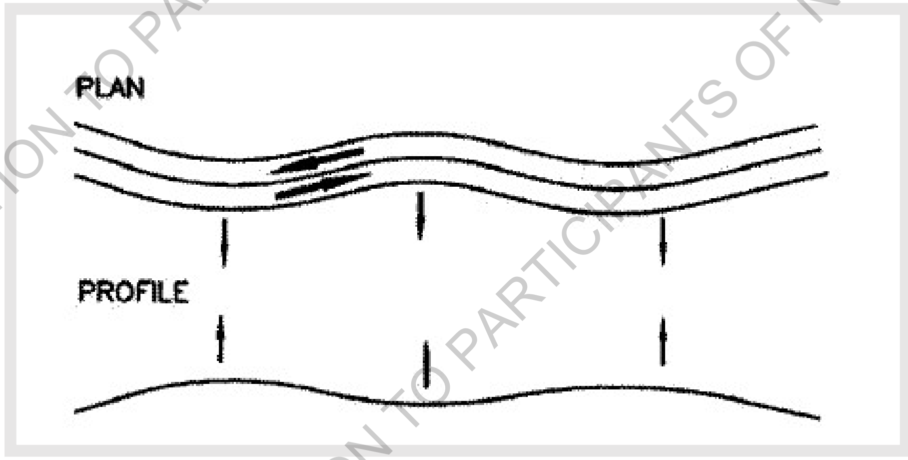
Coordination of Vertical and Horizontal Alignment

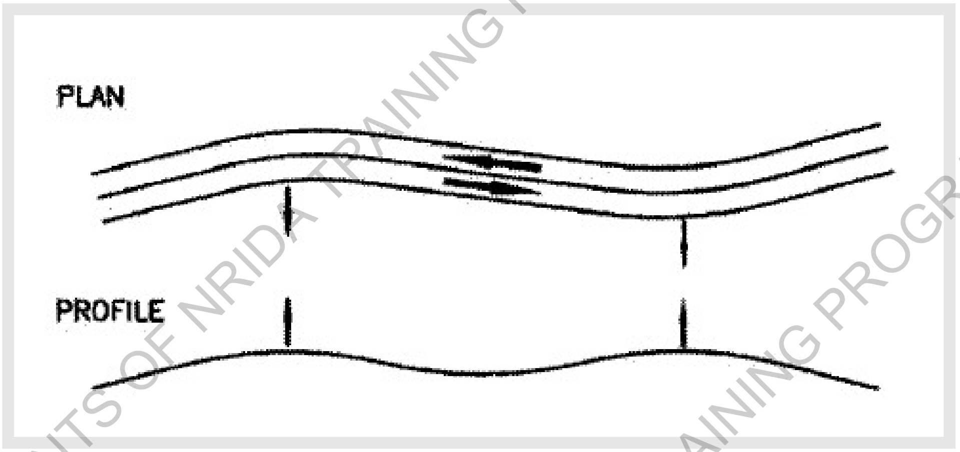
- Horizontal curvature and grade should be in proper balance
- Avoid:
  - Excessive horizontal curvature to achieve flat grades
  - Excessive grades to achieve flat curvature

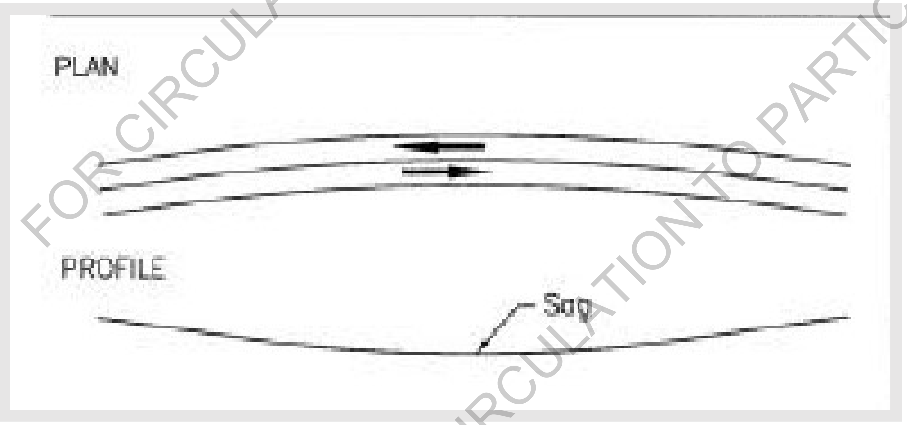
Coordination of Vertical and Horizontal Alignment

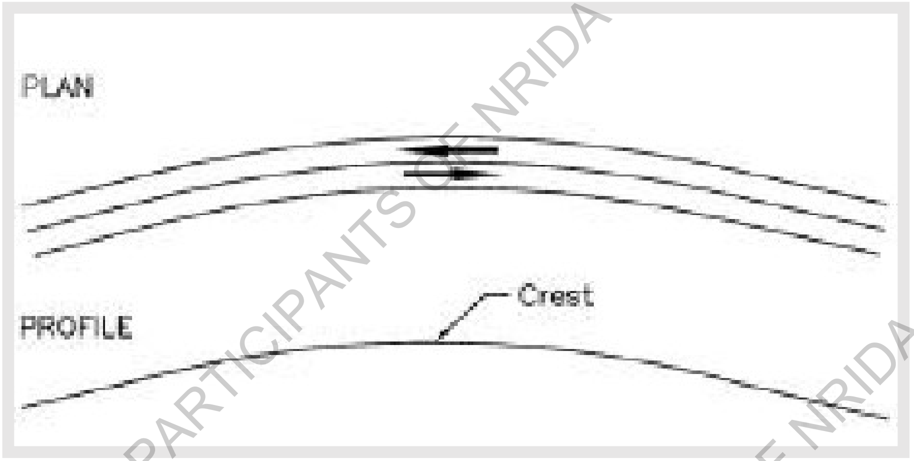
- **Sharp horizontal curvature should not be introduced at or near the top of a pronounced crest vertical curve**
  - Drivers may not perceive change in horizontal alignment esp. at night
- **Sharp horizontal curvature should not be introduced near bottom of steep grade near the low point of a pronounced sag vertical curve**
  - Horizontal curves appear distorted
  - Vehicle speeds (esp. trucks) are highest at the bottom of a sag vertical curve can result in erratic motion

Examples of “Good” Coordination

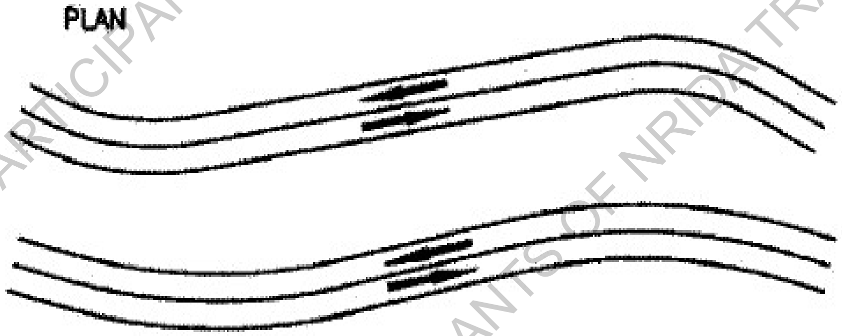






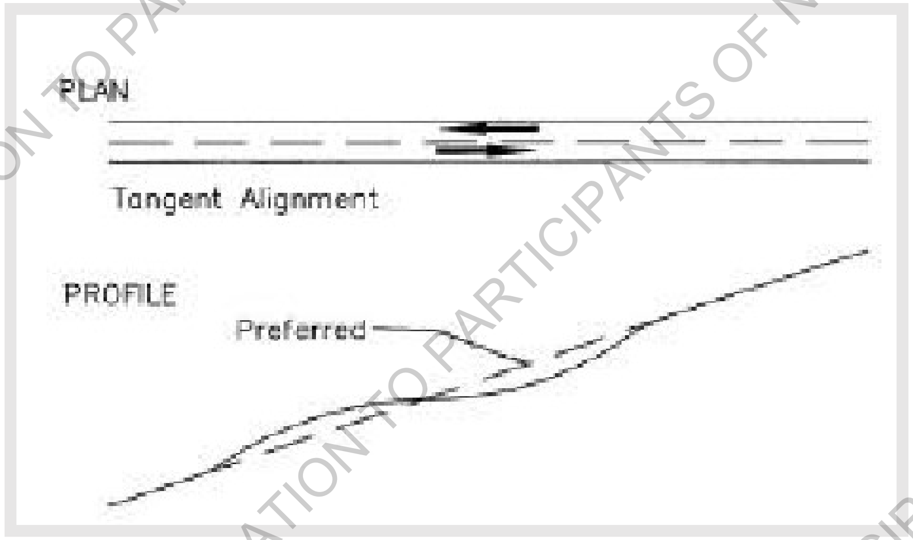


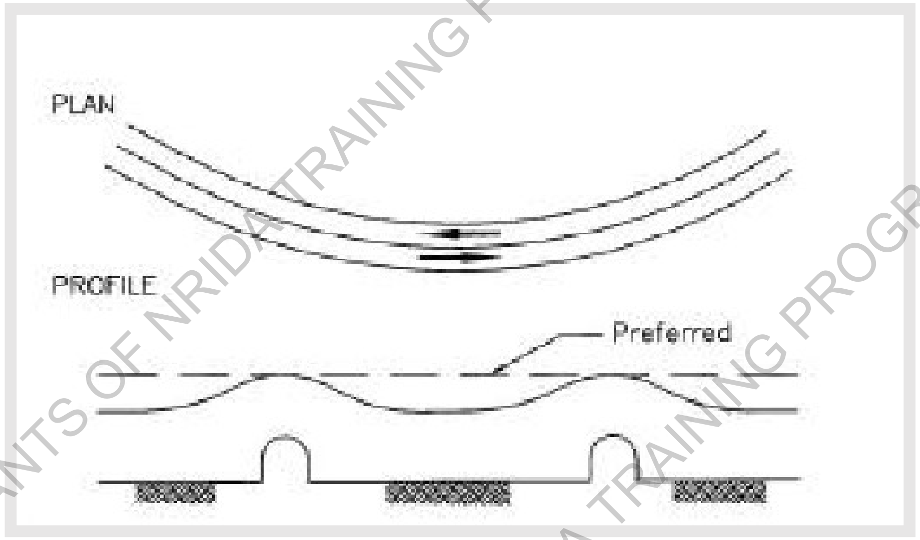
Examples of “Good” Coordination

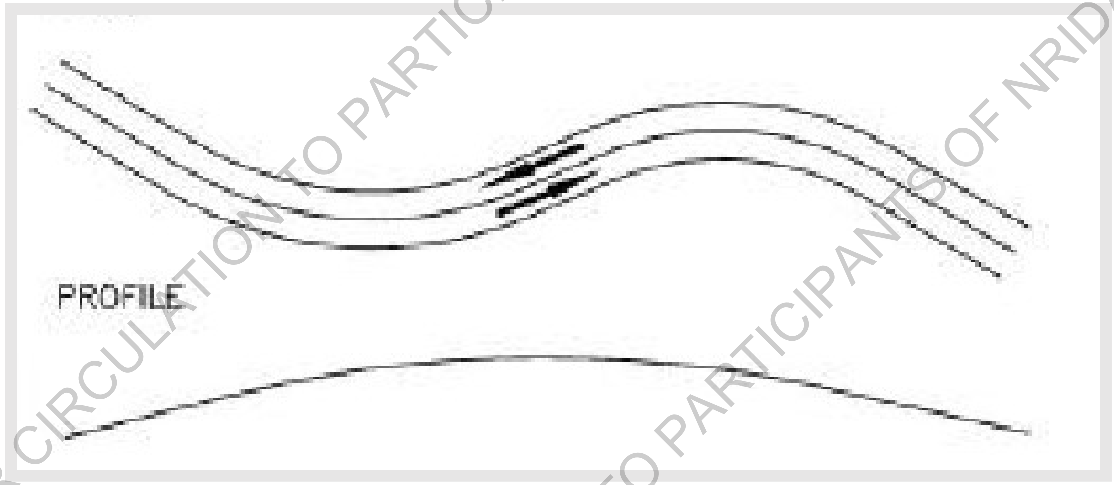


The upper line is an example of poor design because the alignment consists of a long tangent with short curves, whereas the balance between the curves and tangents in the lower alignment is the preferred design.

Examples of “Bad” Coordination of Alignment







Examples of “Bad” Coordination of Alignment

Application
of
Geometric Design of Roads

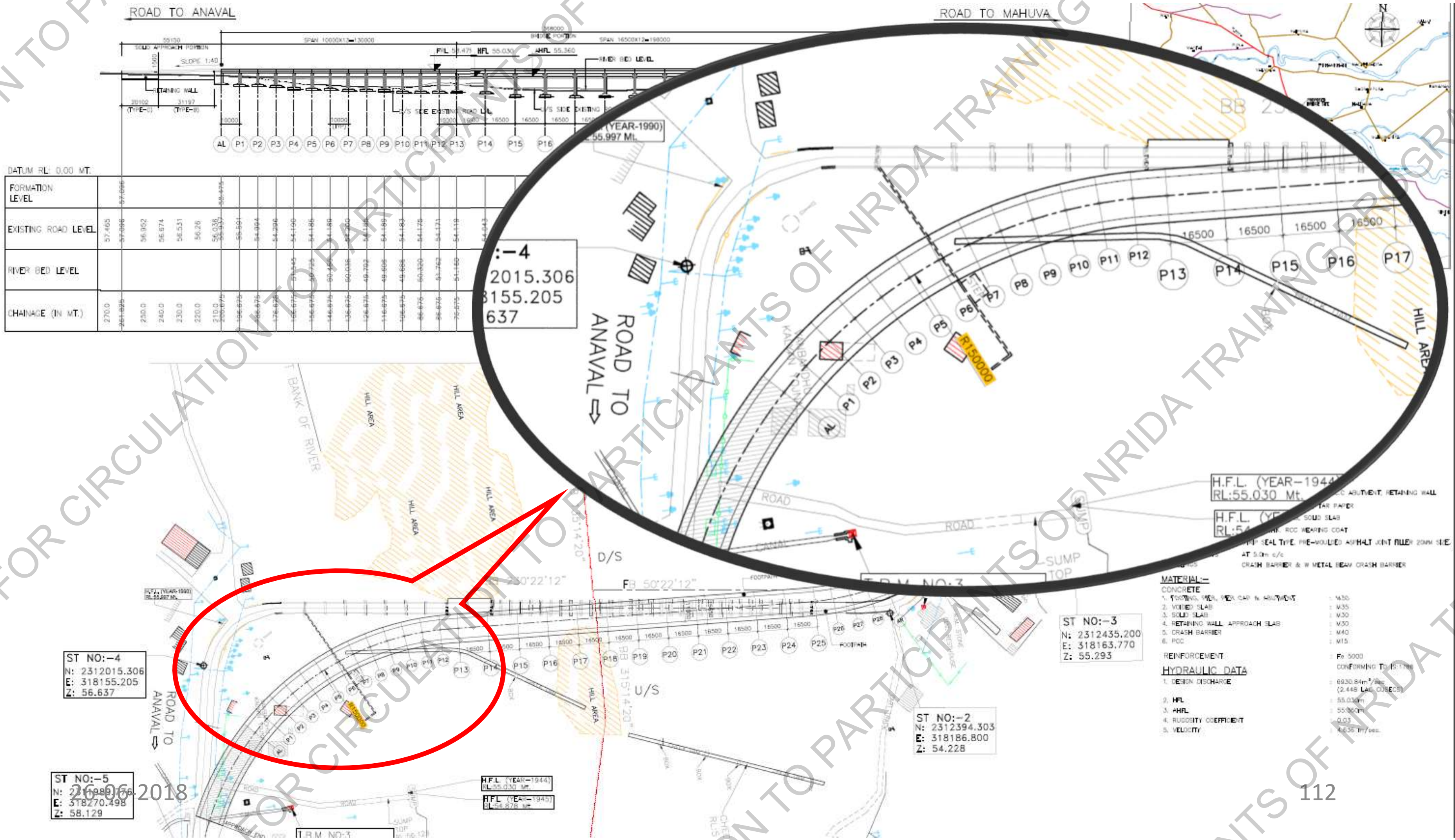
Accidents due to lake of safety provisions

MAULI KRUPA
SONU

Lack of safety at Work zone

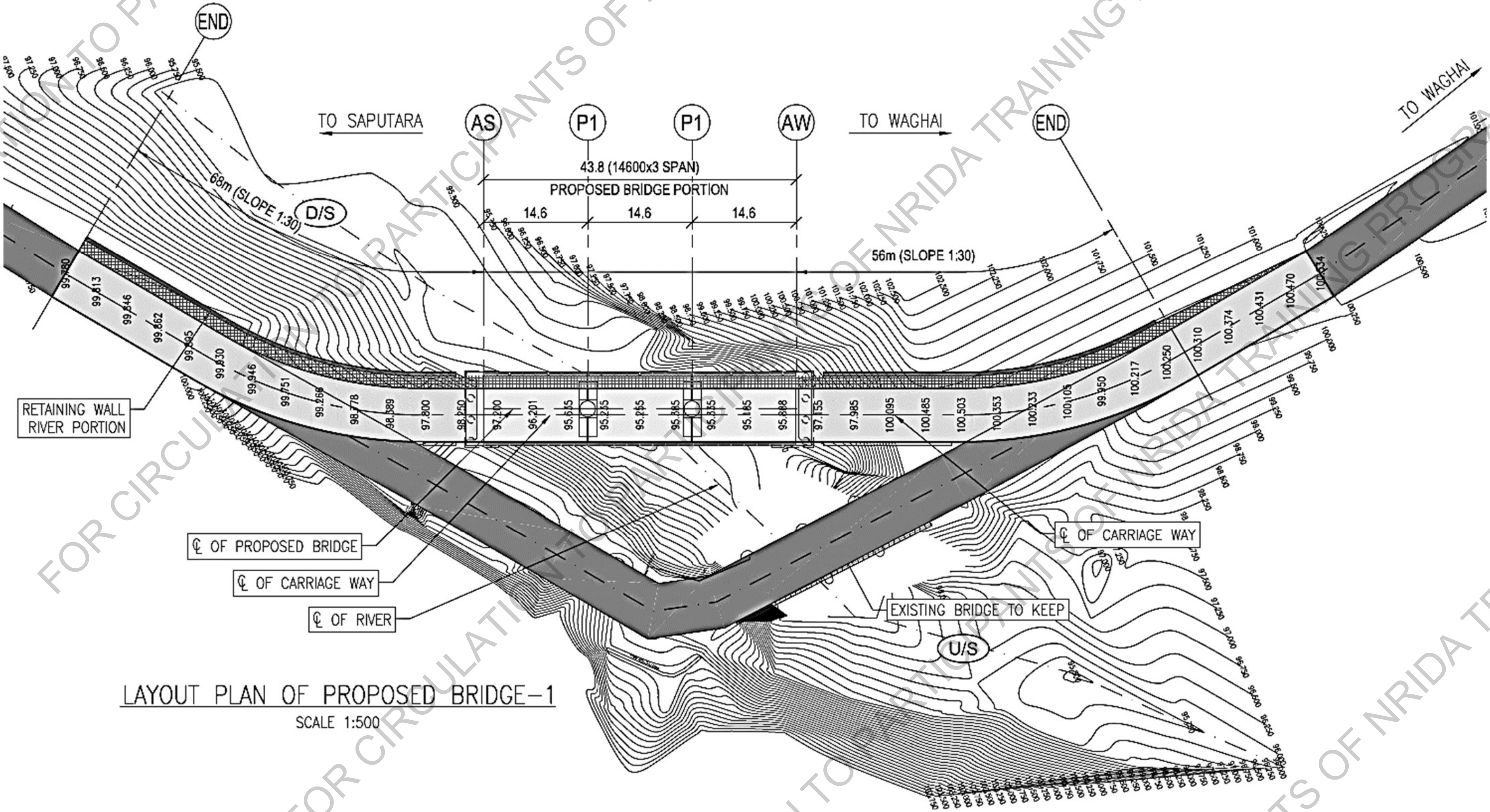
Case study: Alignment improvement

(Ambika river bridge on Mahuva-Anval road)



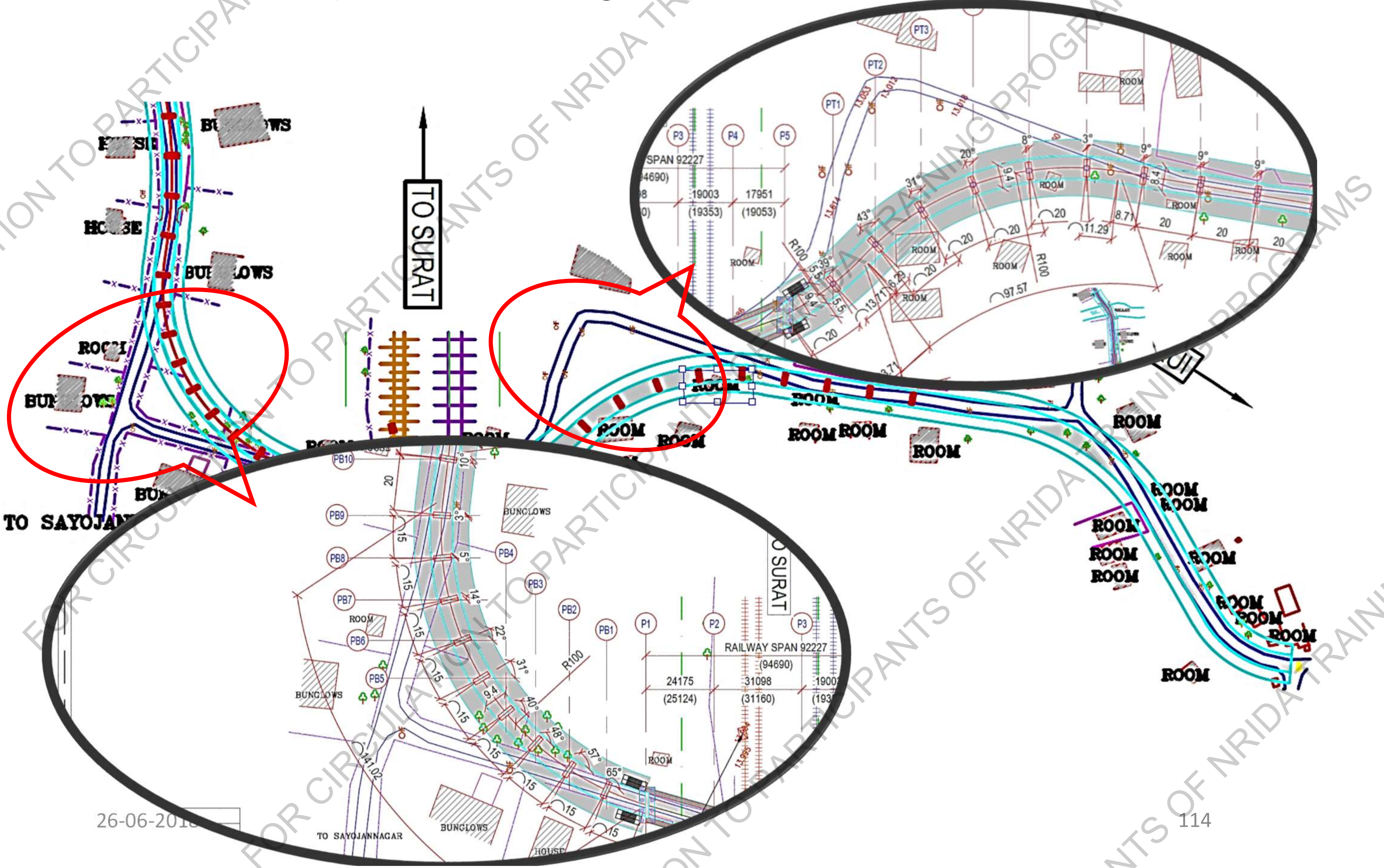
Case study: Alignment improvement

(Waghai-Saputara road)



Case study: Alignment improvement

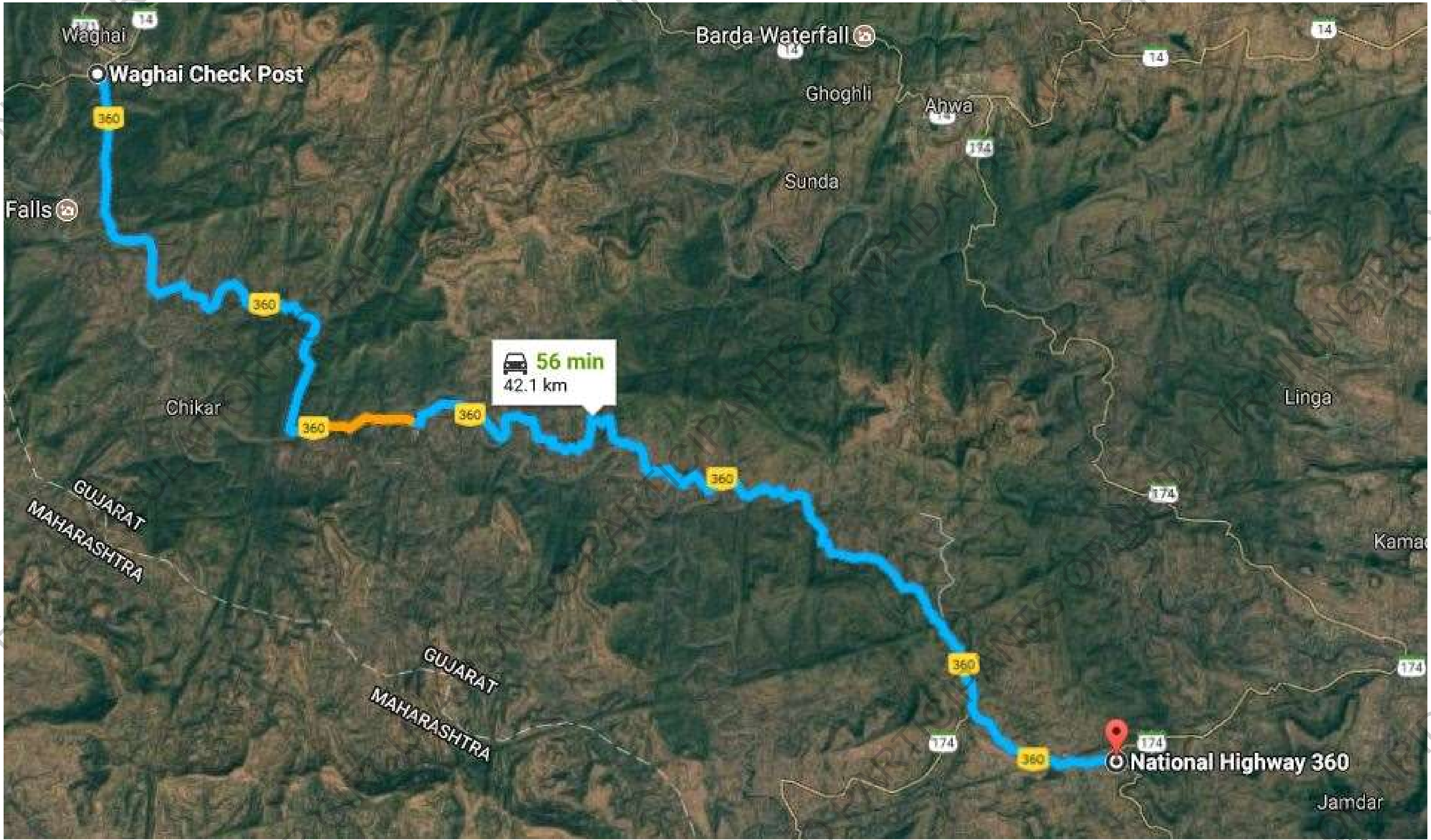
(Ambika river bridge on Mahuva-Anval road)



Critical Examples

Study Name	NH 360
Study Stretch	Waghai to Samgahan Village
Chainage	61+0 to 103+3
Stretch Length	42.3 km
Background Information Available	Road network plans Relevant Documents Accident Information

Satellite View of the stretch



EXISTING CONDITION OF ROAD

- **No adequate sight distance** provided at horizontal curves.
- **No safe overtaking** opportunities provided.
- Steel barrier can be provided at outer edge of horizontal curve where the embankment height is more than 2.5 meter.
- **Side shoulder** is not being provided for the entire stretch, hence paved side shoulder is being recommended.
- Road surface quality may improve to fulfill the requirement of commuters comfort ability.

Critical Location Identified

61/68

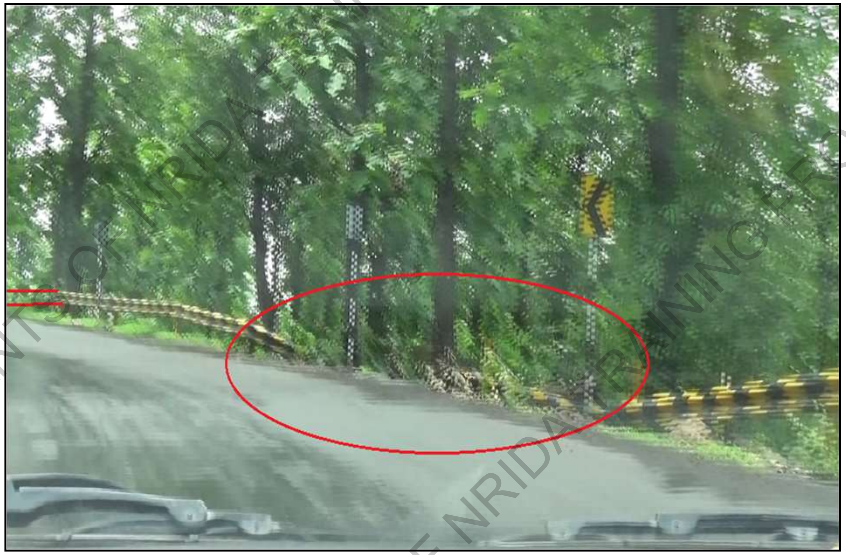
62/06

70/22

71/99

Critical Location Identified

64/09



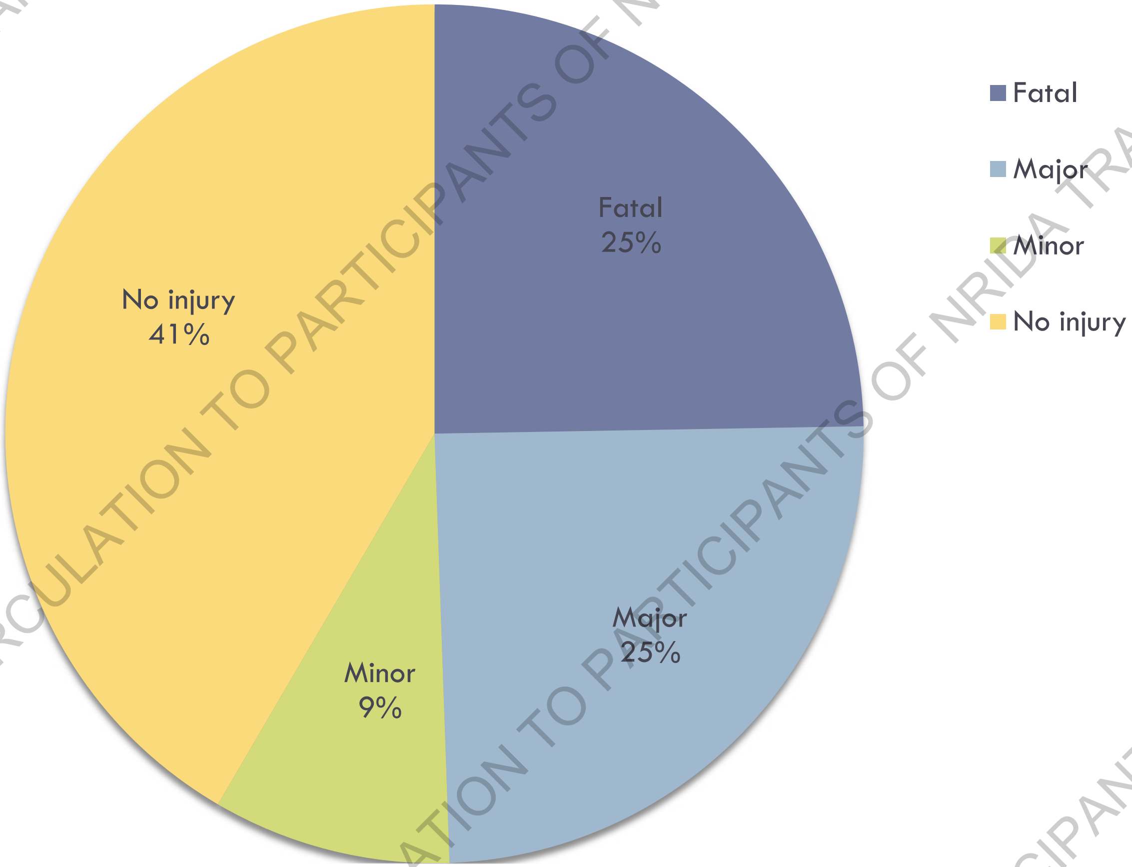
91/66

Accident data for the stretch

- Total **94** accident data were obtained from this corridor for chainage of 61/00 to 103/3.

- Among them five accidents were neglected, as adequate accident details were not available.

Accident Severity Proportion



- Here, critically observed fatal accident proportion is same as that of Major accidents, i.e. **25%.**

Critical Location Identified Based on Accident Data

Accident severity	No. of accidents observed
Fatal accidents	22
Major accidents	22
Minor accidents	8
No injury accidents	37

Chainage	Nearby Location	Maximum no. of accidents
From 68/2 to 68/4	Jamla pada Village	14
From 77/4 to 77/6	Nana pada Village	8

Chainage	Nearby Location	Maximum number fatal accidents
From 68/2 to 68/4	Jamla pada Village	6
From 82/6 to 82/8	Nana pada Village	3

Clips Of the Critical Points

Chainage-68/2

Chainage-82/6

Chainage-73/2

Improvement of Curves at critical locations

Based on the available accident data and the geometry of the stretch, three critical horizontal curves were identified at:

- Chainage: 68/2 to 68/4
- Chainage: 70/8 to 71/0
- Chainage: 73/2 to 73/4

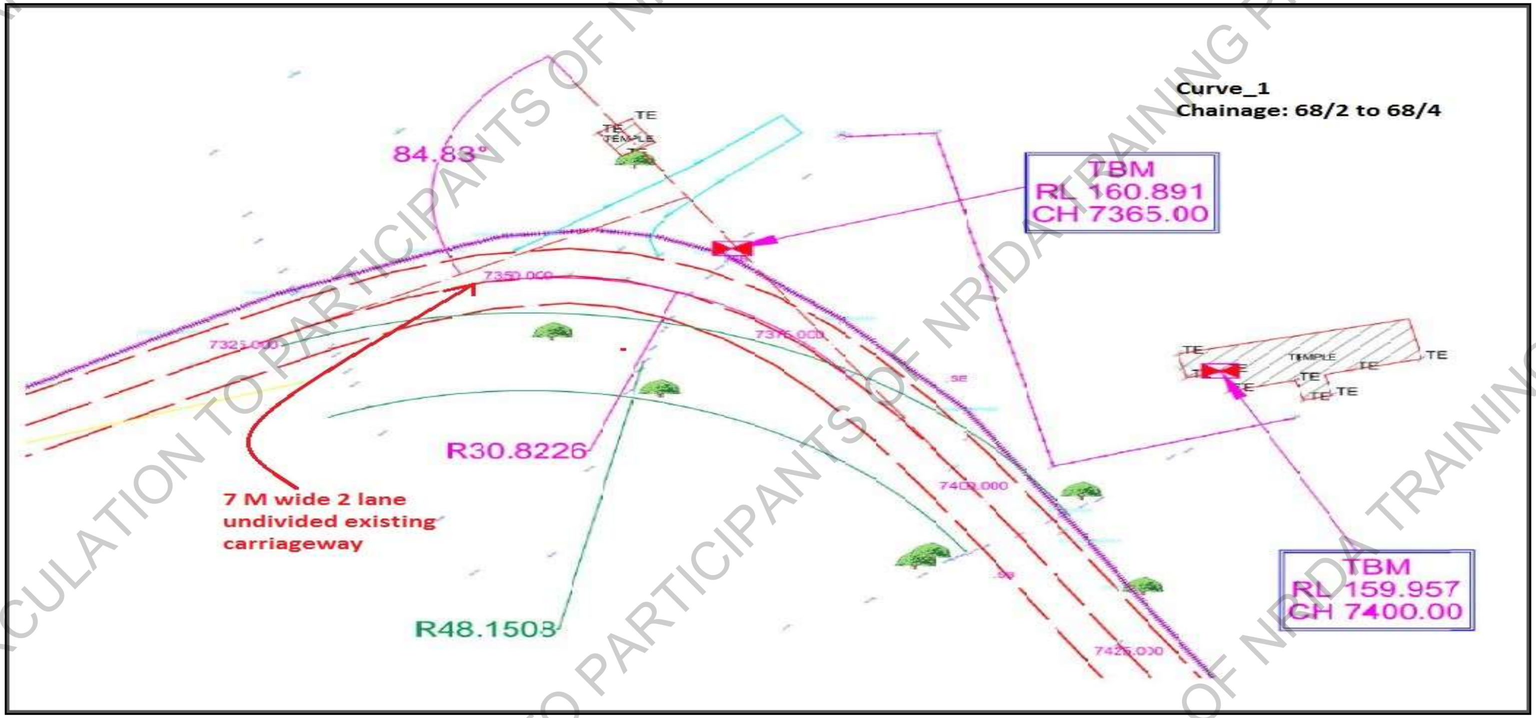
Improvement recommendations were given for these three curves based on **IRC 73 : 1980** (geometric design standards for rural non urban highways)

Improvement of Curve_1 (Chainage: 68/2 To 68/4)

Existing curve characteristics

- Chainage: 68/2 to 68/4
- Accident type: Multiple Fatal accidents
- Existing Radius: 30.82 m
- Existing Carriageway : 7 m
- Existing ROW: 15 m

Improvement of Curve_1 (Chainage: 68/2 To 68/4)



Proposed Radius: 48 m + proposed Transition length of 40 m @ 40 KMPH speed.

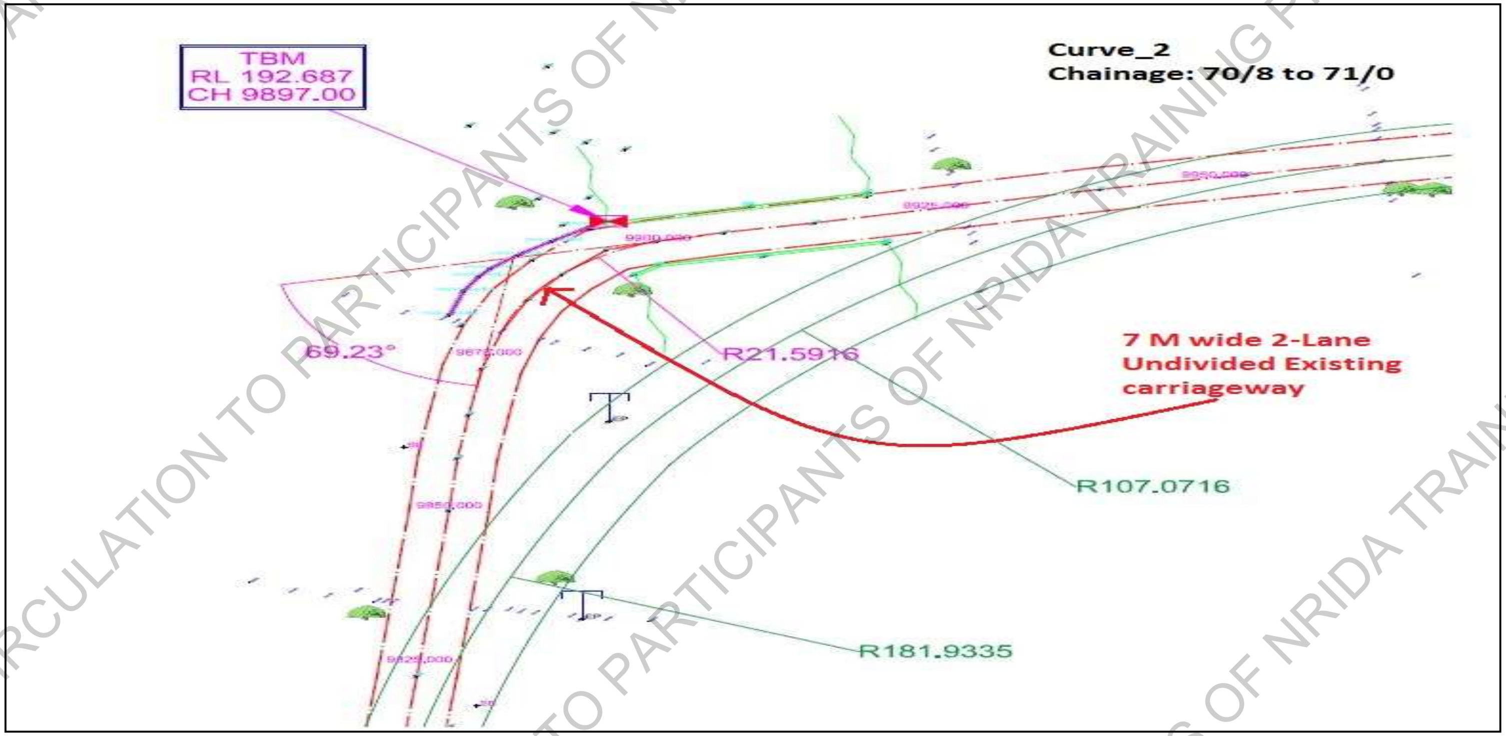
As per the Proposed Radius, required Lane width should be 18.5 m which is not available. Thus, as per IRC 73:1980, it is recommended to reduce the design speed to **25 KMPH with no Transition Length and radius of 30.82 m.**

Improvement of Curve_2 (Chainage: 70/8 to 71/0)

Existing curve characteristics

- Chainage: 70/8 to 71/0
- Accident type: Multiple Fatal accidents
- Existing Radius: 21.59 m
- Existing Carriageway : 7 m
- Existing ROW: 15 M

Improvement of Curve_2 (Chainage: 70/8 to 71/0)



Proposed Radius: 107 m + proposed Transition length of 20 m @ 40 KMPH speed.

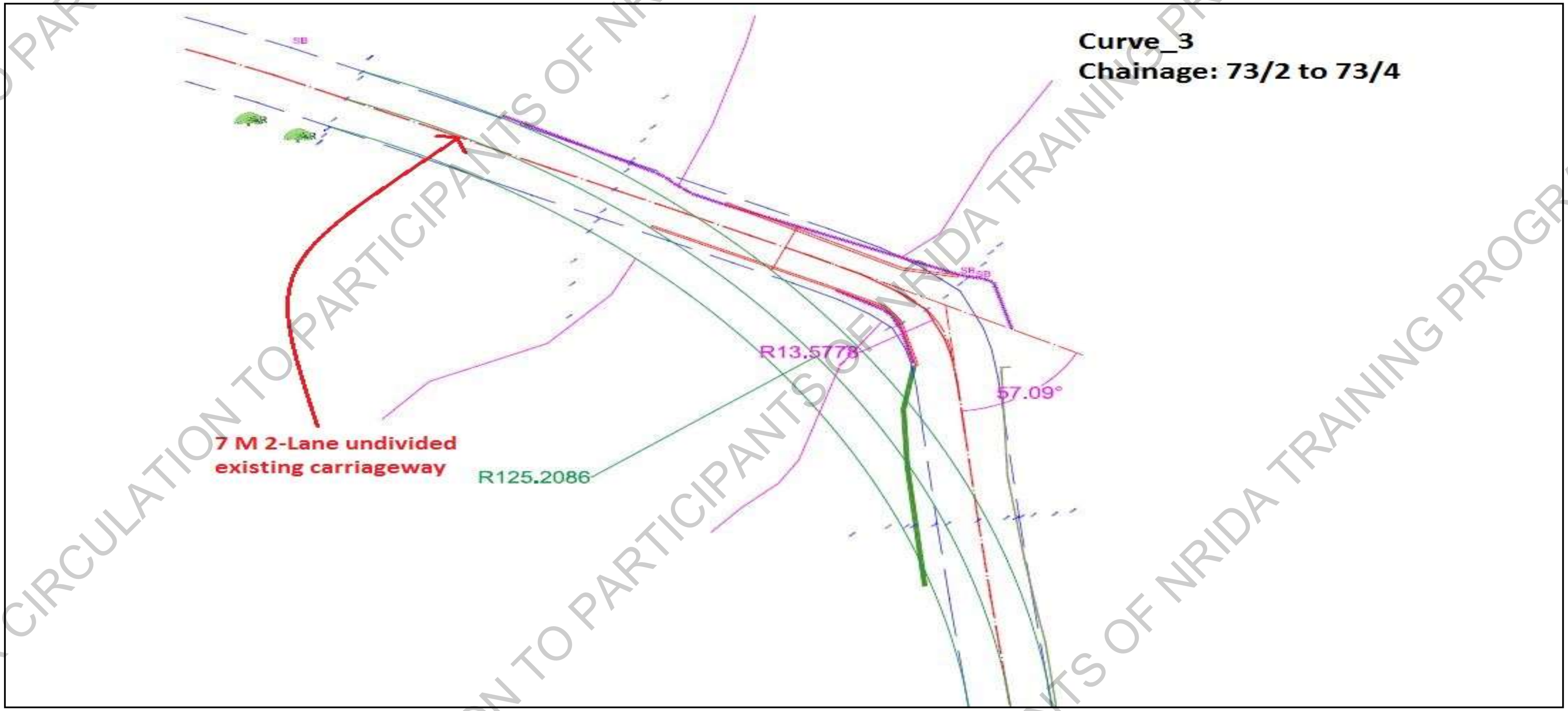
As per the Proposed Radius, required Land width should be 30.5 m which is not available moreover the alignment is passing through culvert. Thus, as per IRC 73:1980, it is recommended to **reduce the design speed to 25 KMPH with no Transition Length and radius of 21.59 m.**

Improvement of Curve_3 (Chainage: 73/2 to 73/4)

Existing curve characteristics

- Chainage: 73/2 to 73/4
- Accident type: Multiple Fatal accidents
- Existing Radius: 13.57 m
- Existing Carriageway : 7 m
- Existing ROW: 15 M

Improvement of Curve_3 (Chainage: 73/2 to 73/4)



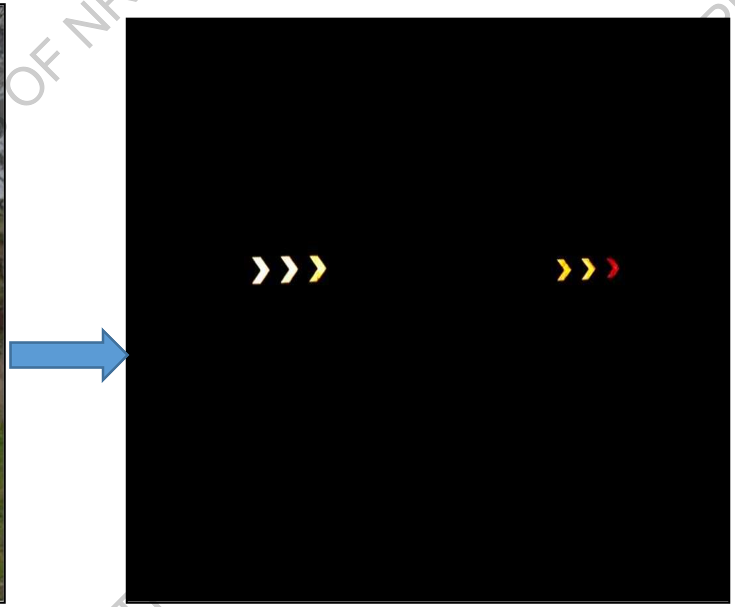
Proposed Radius: 125 m + proposed Transition length of 20 m @ 40 KMPH speed.

As per the Proposed Radius, required Land width should be 25.53 m which is not available moreover the alignment is passing through culvert. Thus, as per IRC 73:1980, it is recommended to reduce the **design speed to 25 KMPH with no Transition Length and radius of 13.57 m.**

Good practice of providing Rumble strips before horizontal curve with CD work

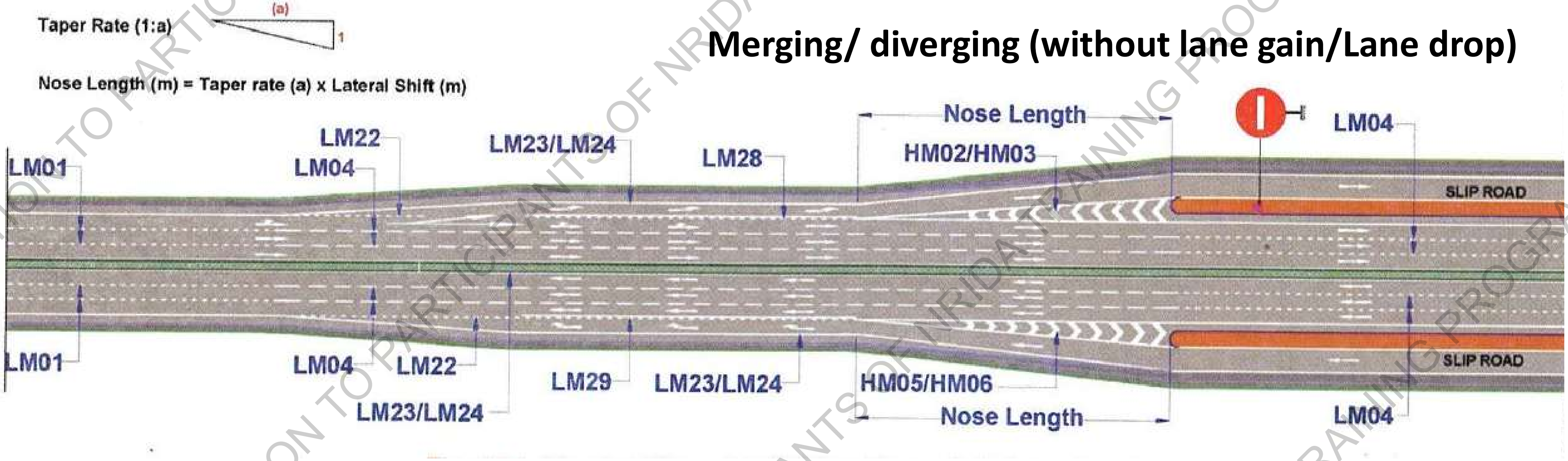
Other Important Recommendation

In addition to changes mentioned it is also recommended to use the Chevron, road studs and signs to improve the night driving quality at sharp curves wherever possible.

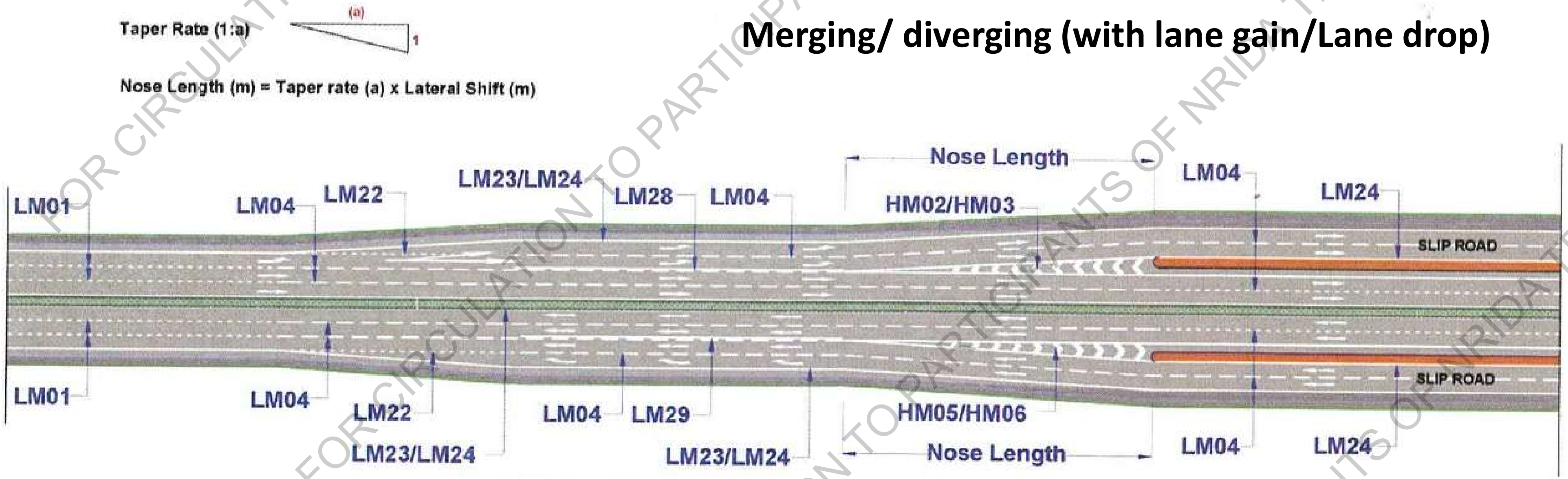


- **Merging** of roadway or service lane after/ Before bridge should be **tapered with diagonal markings, Hazardous sign** board etc. as given in IRC:35-2015.

Merging/ diverging (without lane gain/Lane drop)



Merging/ diverging (with lane gain/Lane drop)



Thank You