Traffic Calming Measures

NIRMAL JIT SINGH
FORMER DG (RD) & SS, MORTH

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History of Traffic Calming

- Traffic Calming began in Netherlands in 1960s with the design of “Woonerven” or “living yards”
- Woonerven integrated motor traffic with pedestrian and bicycle traffic on shared street space
- In 1970s Germany began working in the area using the term “Verkehrs beruhigung” which is translated as traffic calming
- Spread to other countries in Europe, Canada and Australia
- In late 1970s a number of communities in USA began applying principles of traffic calming

Background

- Concept of traffic calming is fundamentally concerned with reducing the adverse impact of motor vehicle on built up areas
- Usually involves reducing vehicle speeds, providing more space for pedestrians & cyclists and improving the local environment
- Traffic calming techniques are now applied to whole areas of towns and not just to individual streets.
- Main traffic arteries, villages, shopping street, and town centres have all been included.
- Area wise traffic calming schemes seek to calm both the main roads and the residential roads in an area.

Background (Contd..)

- Traffic Calming techniques emerged primarily as society's requirement for safety.
- Widely accepted that differences and variations in speed direction and mass of vehicles are key factors in severity of accidents.
- Over the last 25 years, residential areas in Europe have become much safer with creation of 30 km/hr zones.
- Several experiences around the world have established that Traffic Calming techniques to influence road design significantly reduces accidents, pollution and makes neighbourhoods more livable.

Traffic Calming

Traffic calming involves changes to street alignment, installation of barriers and other physical measures to reduce traffic speeds and/or cut through traffic. Goal of traffic calming are:

- Reducing vehicle speed
- Improving safety
- Enhancing Quality of life

Need for Traffic Calming techniques in Indian Scenario

- Different categories of Roads viz NH, SH, MDR, ODR, urban roads designed for different design speeds.
- Heterogeneity of modes of traffic on most roads.
- Sometimes tractors and animal carts share the carriageway with fast moving motorised traffic.
- Highways that pass through villages and towns are also shared with local traffic resulting in wide variation in direction, speed and vehicle mass.
- Road construction and maintenance are expensive public expenditure and costs on road users and overall society are also substantial.

Need for Traffic Calming techniques in Indian Scenario (Contd..)

- Social costs comprising of accidents involving injuries and death and pollution in surrounding areas are difficult to quantity.
- Imperative to pursue policies that minimise transportation costs for individual road links and network as a whole using limited financial resources efficiently.
- Extensiveness and diversity in road network create opportunities to explore wide range of traffic calming techniques.

India v/s Developed Countries

S. No.	Feature	India	High Income Countries
1	Modal mix of traffic in urban areas	Two-wheelers, three wheelers and non-motorised traffic comprise a much larger share of traffic than cars	Cars are the dominant mode
2	Modal mix on intercity roads	Trucks and buses constitute a larger share than cars on most highways. Presence of tractors and non-motorised traffic. Large variation in speeds.	Again, cars are the dominant mode and there are no tractors and non-motorised traffic. Therefore, little variation in speeds.
3	Highways passing through townships.	Almost all intercity roads pass through townships and villages at present. Therefore, all intercity traffic must interact with local traffic when passing through these areas. This situation is likely to remain for quite some time.	Extensive network of limited access highways ensures that most long-distance traffic uses the same. Traffic on intercity roads passing through townships is generally not long distance traffic and hence has slightly different characteristics and needs.

India v/s Developed Countries (Contd..)

S. No.	Feature	India	High Income Countries
4	Vehicle characteristics	The suspension systems of vehicles and their sizes vary greatly. Therefore, horizontal TC measures like lane narrowing and staggering would have to be re-explored to deal with narrow vehicles. Vertical measures like humps (speed breakers) would affect cars, motorcycles, trucks and buses differently.	Since the vast majority of vehicles are cars and even larger vehicles, horizontal measures are effective. Vertical measures must be tailored to cars, buses and trucks and two-wheelers-not a major issue.
5	Traffic segregation	Very little segregation of traffic. TC measures should target segregation as one of the major goals.	A large proportion of roads in Europe now have segregation of traffic, especially the provision of bicycle lanes thereby making the TC measures easier to implement.

Importance of speed management in accident severity

- Vehicle speed is one of the critical factors associated with road accidents.
- Higher speeds reduce the time available to avoid collisions and makes the impact in collisions more severe.
- Research studies from around the world demonstrate conclusively that frequency and severity of accidents usually reduce with reduction in average speed.
- A decrease in average speed of 1 km/hr will typically result in 3 percent decrease in fatal accident severity.
- Variation in speed between vehicles within the traffic stream is another factor that contributes to accident occurrence.

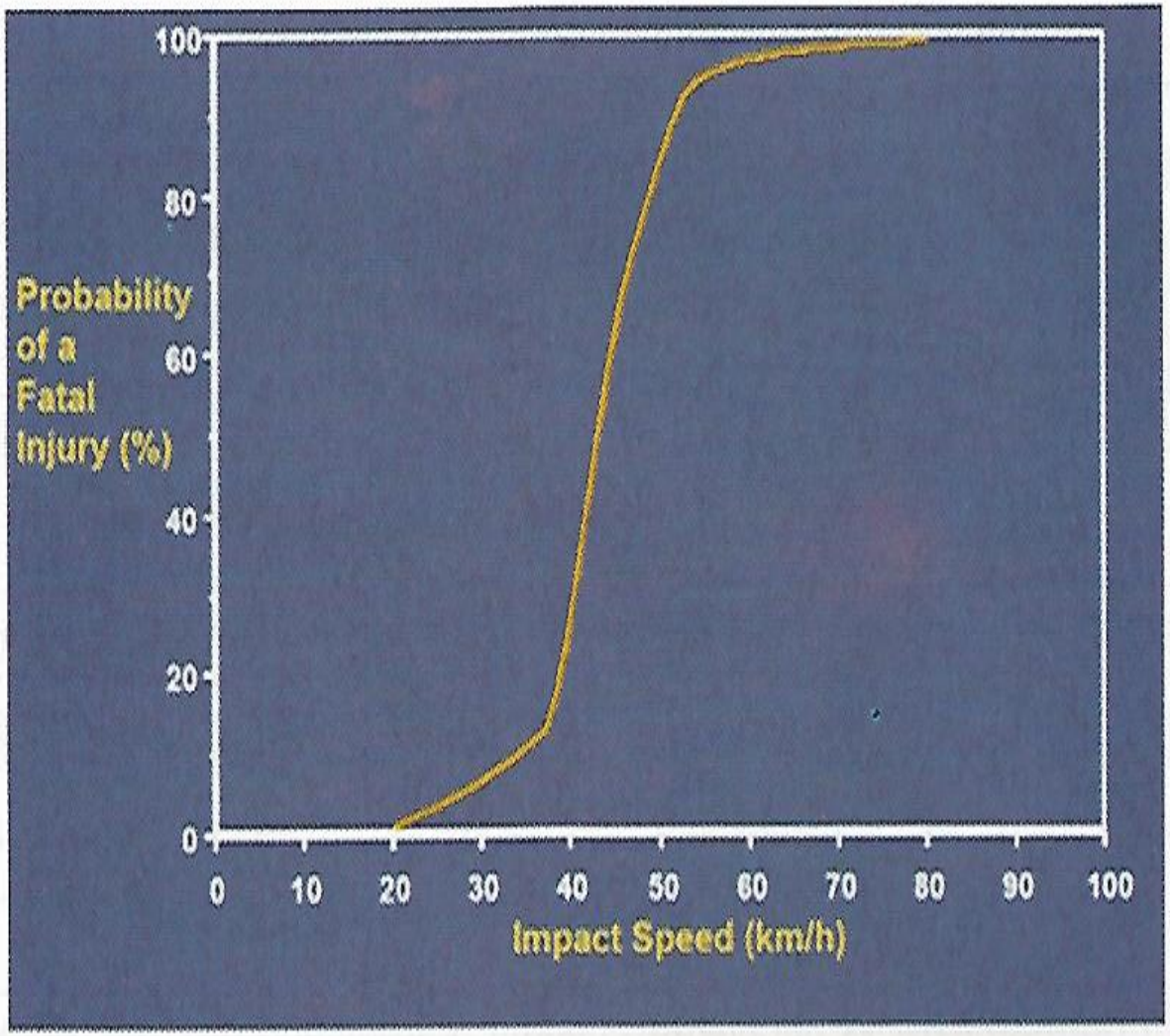


Fig. 1.1 Probability of Fatal Injury for Pedestrian by the Speed of the Car on Impact

Table 1.1 Effect of Death and Injuries by Change in Mean Speed

Change in	Change in Mean Speed					
	Speed Reduction			Speed Increase		
	-10%	-5%	-1%	+1%	+5%	+10%
Deaths	-38%	-21%	-4%	+5%	+25%	+54%
Serious Injuries	-27%	-14%	-3%	+3%	+16%	+33%
Other injuries	-15%	-7%	-1%	+2%	+8%	+15%
Property damage crashes	-10%	-5%	-10%	+1%	+5%	+10%

Necessity of Traffic Calming

- Studies have shown that traffic calming can reduce accident levels by up to 40 percent and have significant impact on reducing the severity of accidents, economic loss and air pollution.
- Main advantage is that it is self enforcing and does not normally require any complex traffic control devices.
- Usually highly cost effective, achieving benefits with a value far greater than the costs.

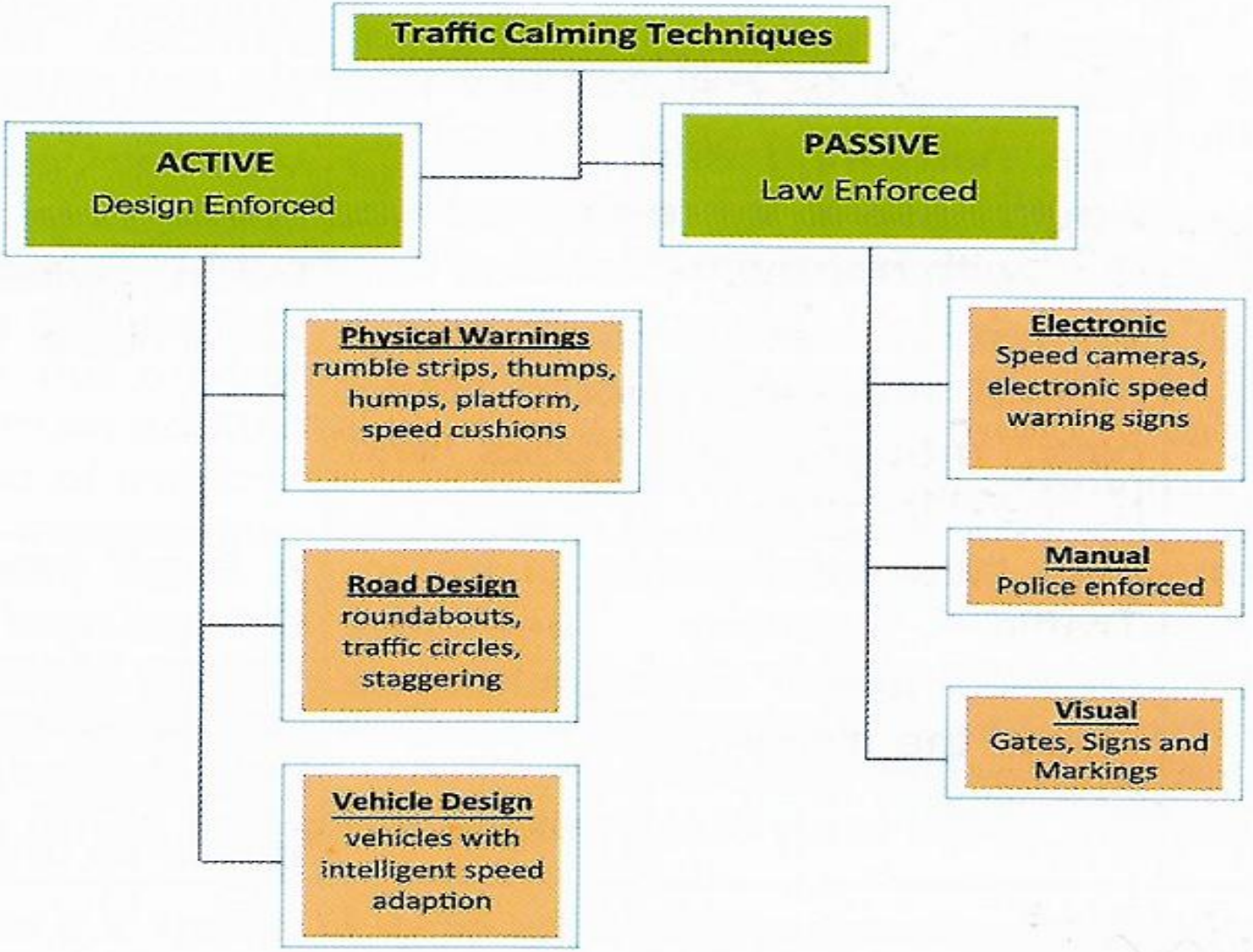


Fig. 2.1 Classification of Traffic Calming Techniques

Active or Design Enforced

- Pro active or design enforced approaches are highly effective since these can achieve almost 100 percent success rates in managing speeds with relatively low level of capital expenditure.
- Roads and vehicles can be designed to achieve a desired response to road and speed classification.
- Appropriate design can address the driver by influencing driver behaviour.
- Such approaches should be preferred method given their high levels of effectiveness and low investments.
-

Influencing Human Behaviour

- A very high percentage of road accidents are attributable to human error.
- Changing human behaviour of drivers and other road users is a slow process and a significant challenge.
- Limitations of the human ability remain evident given the range of behavioural issues and weaknesses – motivation, attention, emotion, observation, prediction, knowledge and skill that prevent human from being an ideal traffic participant.
- Strategies should focus on adopting the transportation system to suit the people who use them so that they are led to behave safely rather than nudging people to adopt to the system.
- Three basic elements of the system – infrastructure, road user and vehicle should be adopted to each other.

Physical Warnings

Table 2.1 Types of Physical Warnings

Intent of TC technique/ intervention	Method	Successful Examples
Physical signal to driver	Influences driver behavior by means of jerks and vibrations to the vehicle	Road humps, rumble strips, raised crossings, plat-form junctions raised at pavement level, speed tables and ramps
Psychological signal to driver	Directly affecting his risk perception by visual or audio means	Carriageway width constrictions, chicanes, corner blips, planted central reservations, bends in the traffic route etc.

Passive or Law Enforced

- Include speed cameras and electronically displayed speed warning signs
- Restrictions enforced by Police manually for certain traffic movement
- Visual measures like gates, signs and markings, whereby Law can be enforced for those who are violating instructions.

Visual Warnings or Pre Warnings

- Pre warnings are applied to ensure that drivers become aware of subsequent speed reducers or changing road speed classification.
- Pre warning is not in itself intended to be physically speed reducing but should motivate the driver to ease the pressure and reduce speed.
- Pre warnings are normally applied on traffic roads before stretches of speed control and can be used for all traffic flows.

Types of Traffic Calming Measures

Speed Control Measures

- Speed Hump
- Speed Table
- Raised Cross Walks
- Raised Intersections
- Textured Pavements
- Traffic Circles
- Round About
- Chicanes
- Central Island Narrowing

Types of Traffic Calming Measures (Cont.)

Volume Control Measures – Divertive, Restrictive

- Full Closure
- Half Closure
- Lateral Shift
- Median Barriers

Methods of Traffic Calming Techniques

- Vertical Deflections
- Horizontal Deflections
- Road Narrowing
- Central Islands

Vertical Deflection

- Vertical Shifts are most effective and reliable of speed reduction measures currently available. Different techniques are
- Road hump
- Several varieties with rounded and flat top being most common
- Plateau (Speed table)

Extend full width of carriageway between the kerbs and extend over a longer length of road than humps

Speed Bumps/Humps

Humps 1.8 m –4.0 m length

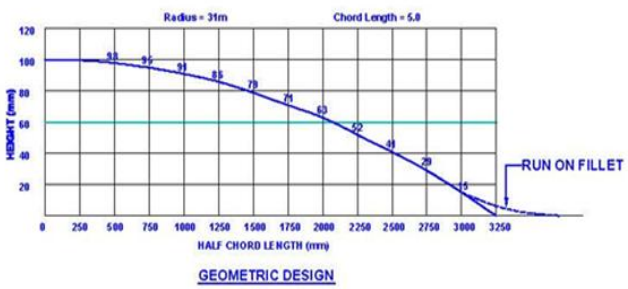
7.5 cm – 10.0 cm height, rounded top

Speed Increases with Length

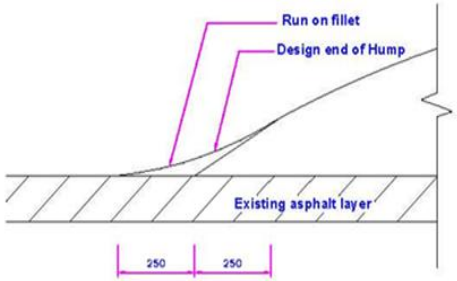
Speed Decreases with Height

Fig. 2.4 Circular Hump – Shape of a Circular Arc

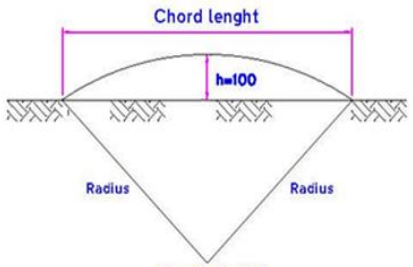
Circular Hump



GEOMETRIC DESIGN



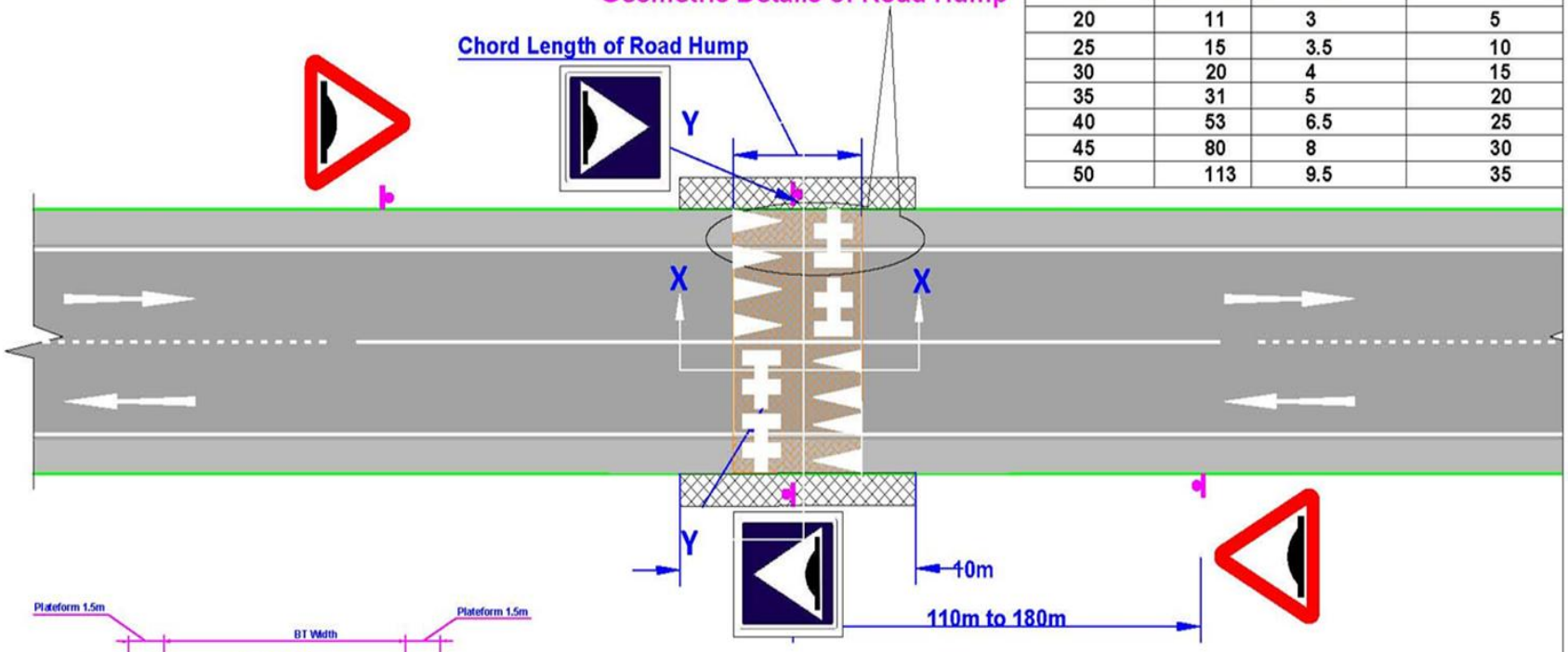
DETAILS OF TRANSITION

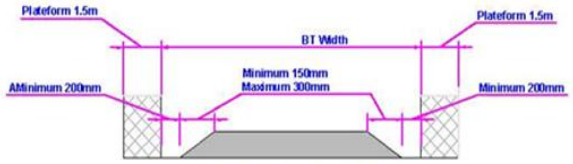


Cross Section X-X

DESIRED SPEED (KMPH)	RADIUS (METER)	CHORD LENGTH (METER)	BUS SPEED DURIN PASSAGE (KMPH)
20	11	3	5
25	15	3.5	10
30	20	4	15
35	31	5	20
40	53	6.5	25
45	80	8	30
50	113	9.5	35

Geometric Details of Road Hump





Cross Section Y-Y

Note: Refer Figure 11.1 of IRC 35 2015 for marking details

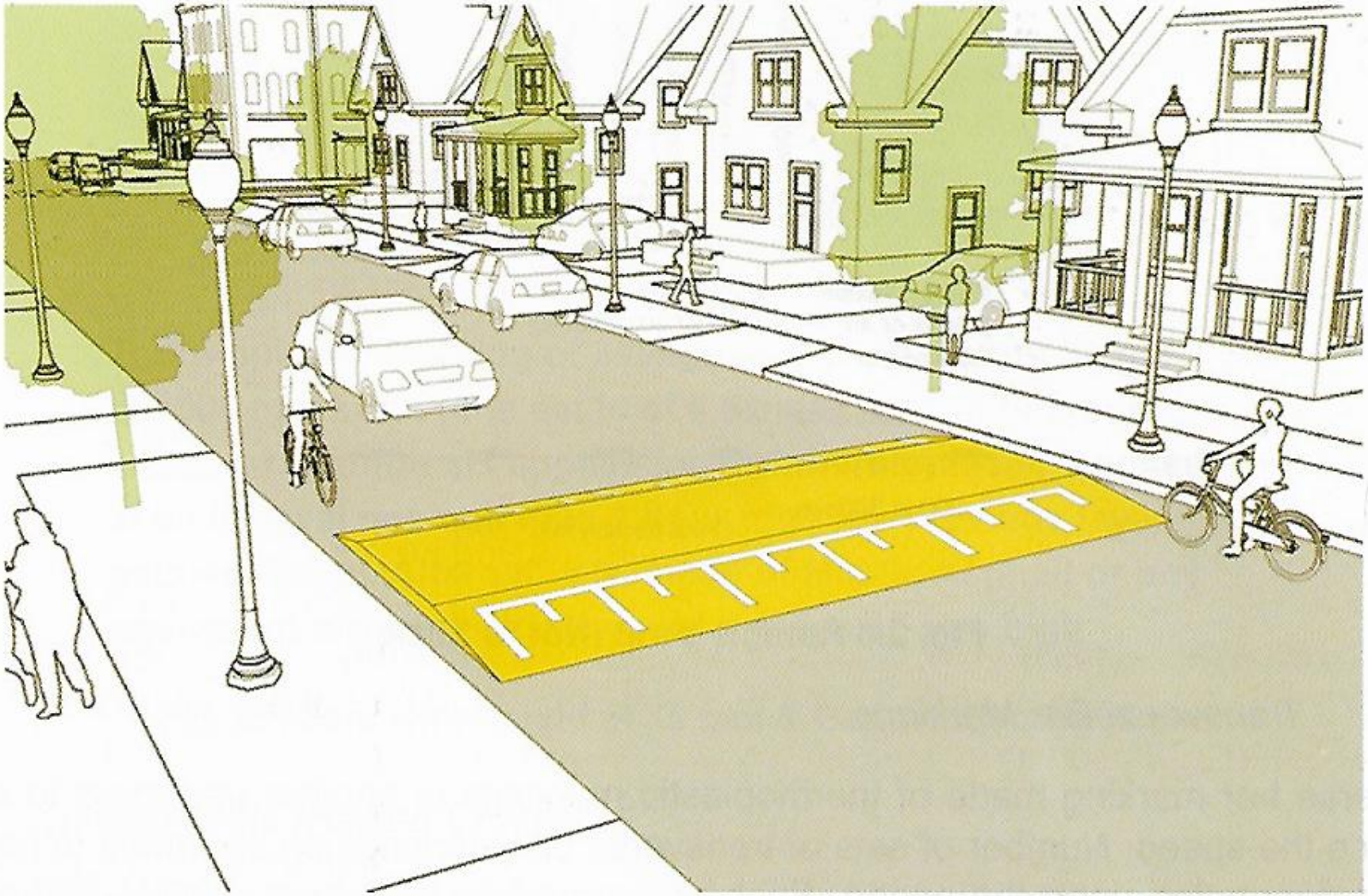
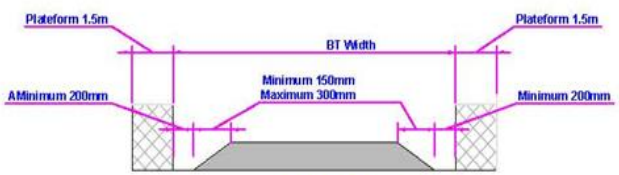
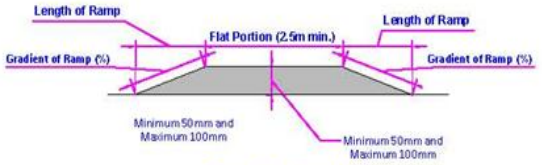


Fig. 2.5 Trapezoidal Hump – Flat Top with Tapered Sides

Trapezoidal Hump



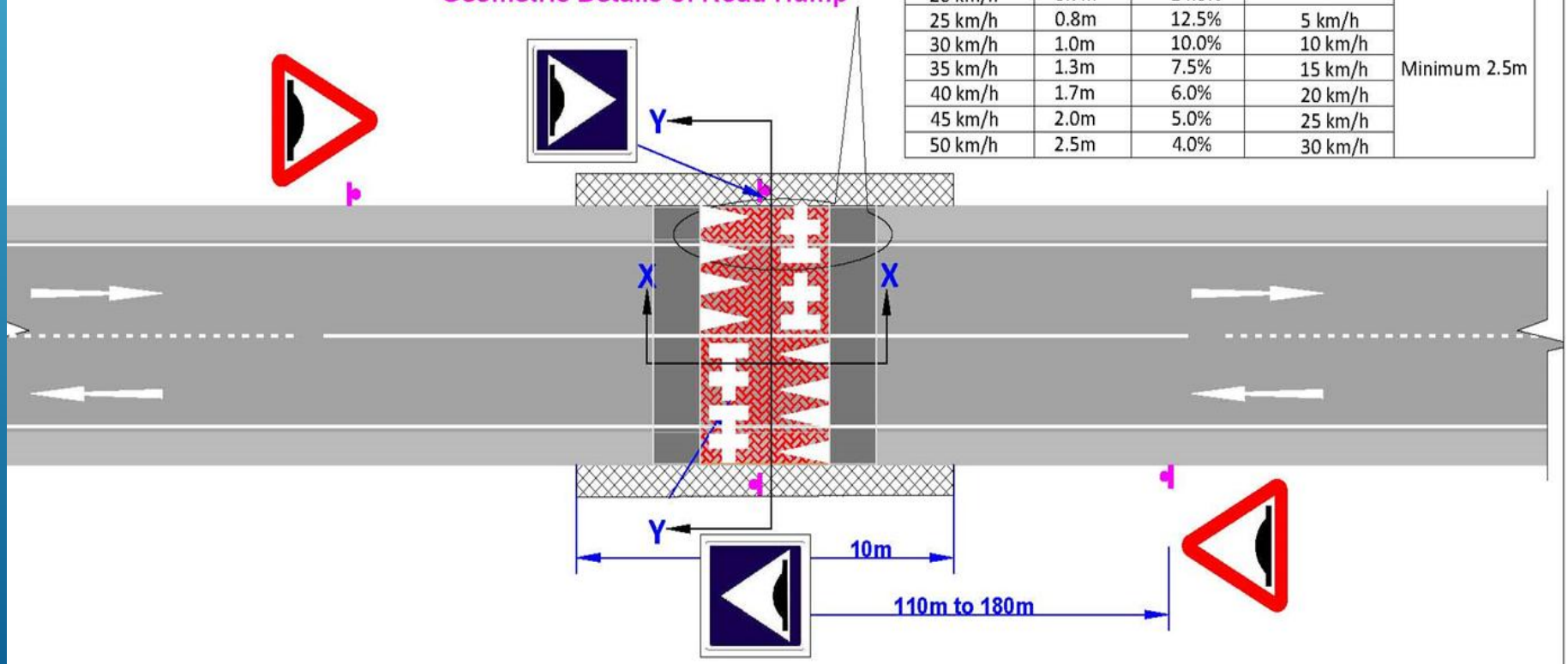
Cross Section Y-Y



Cross Section X-X

Desired Speed (kmph)	Length of Ramp	Gradient of Ramp	Bus speed during passage (kmph)	Length of Flat portion
20 km/h	0.7m	14.0%	-	Minimum 2.5m
25 km/h	0.8m	12.5%	5 km/h	
30 km/h	1.0m	10.0%	10 km/h	
35 km/h	1.3m	7.5%	15 km/h	
40 km/h	1.7m	6.0%	20 km/h	
45 km/h	2.0m	5.0%	25 km/h	
50 km/h	2.5m	4.0%	30 km/h	

Geometric Details of Road Hump



Note: Refer Figure 11.1 of IRC 35 2015 for marking details

H- Hump

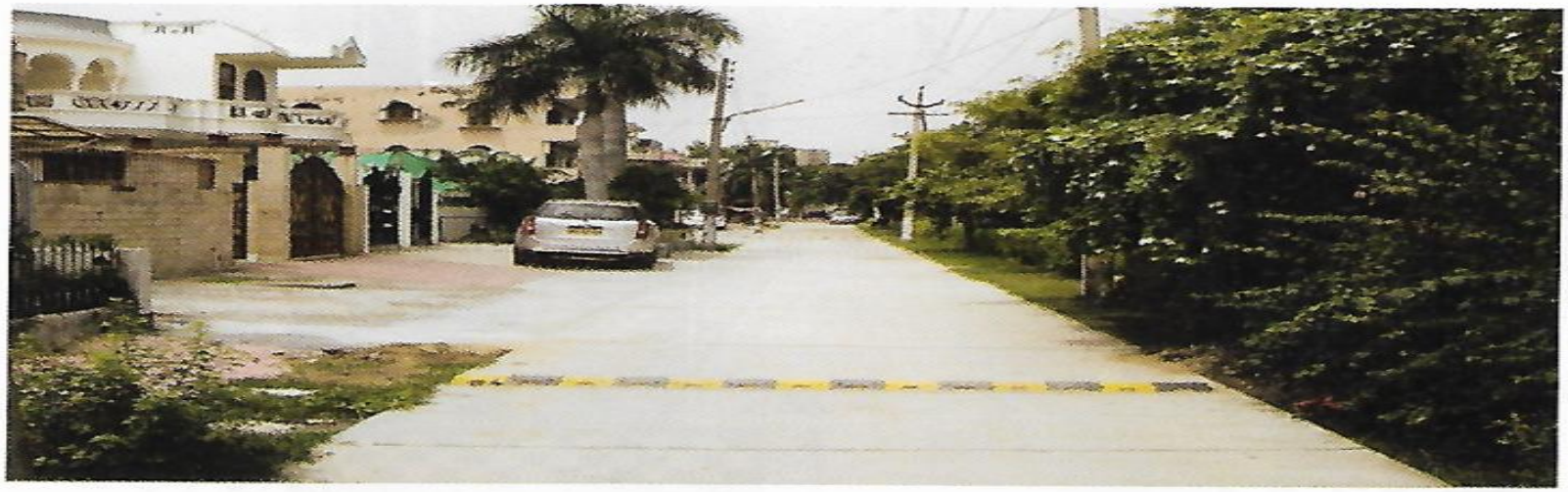


Fig. 3.3 Road Bump in Narrow Residential Street

Fig. 3.4 Road Bump Available in Indian Market

Fig. 3.5 Road Bump in Wide Residential Street

(Gap in the Bump shown in fig. is a Traffic Hazard)

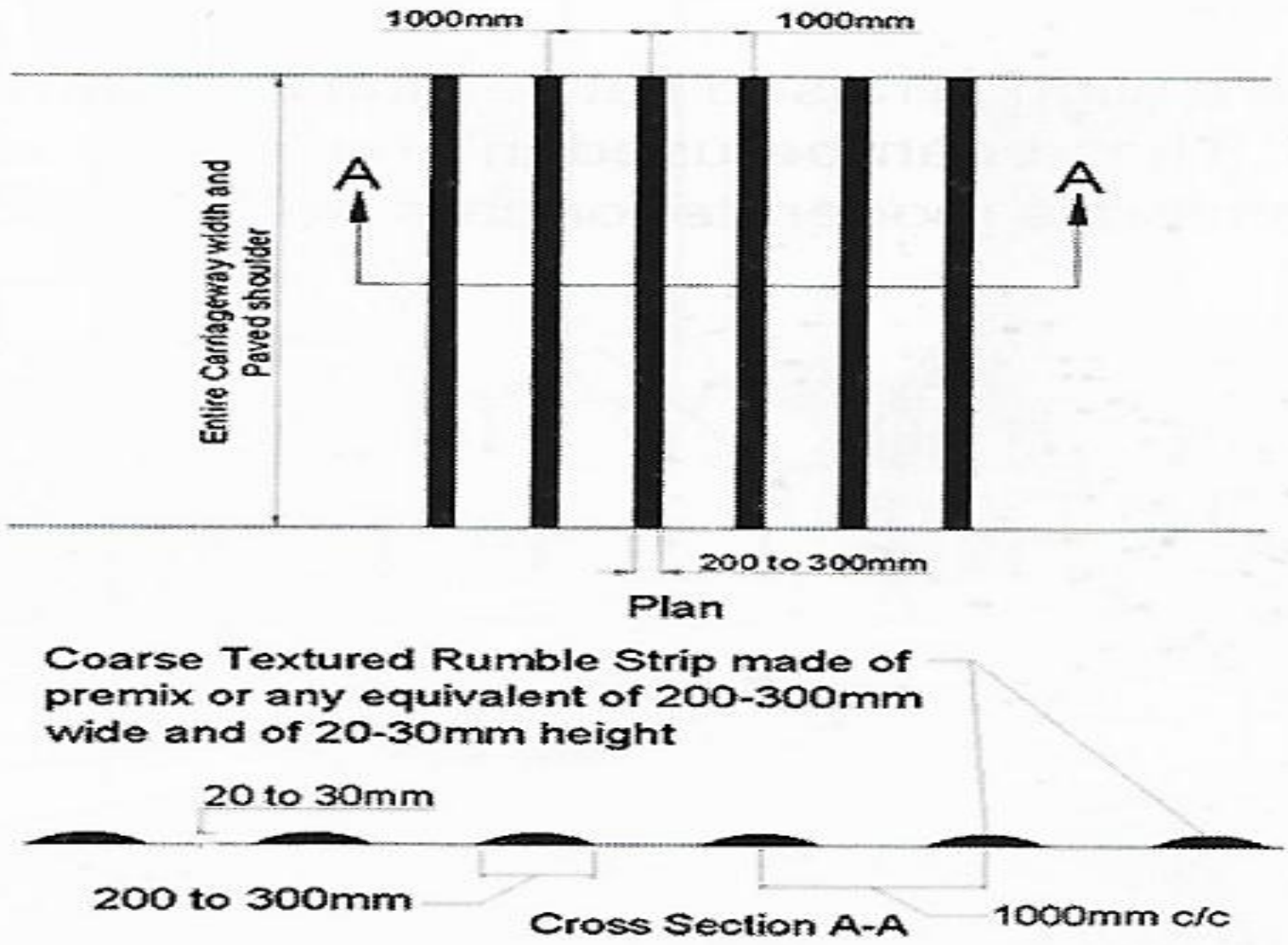
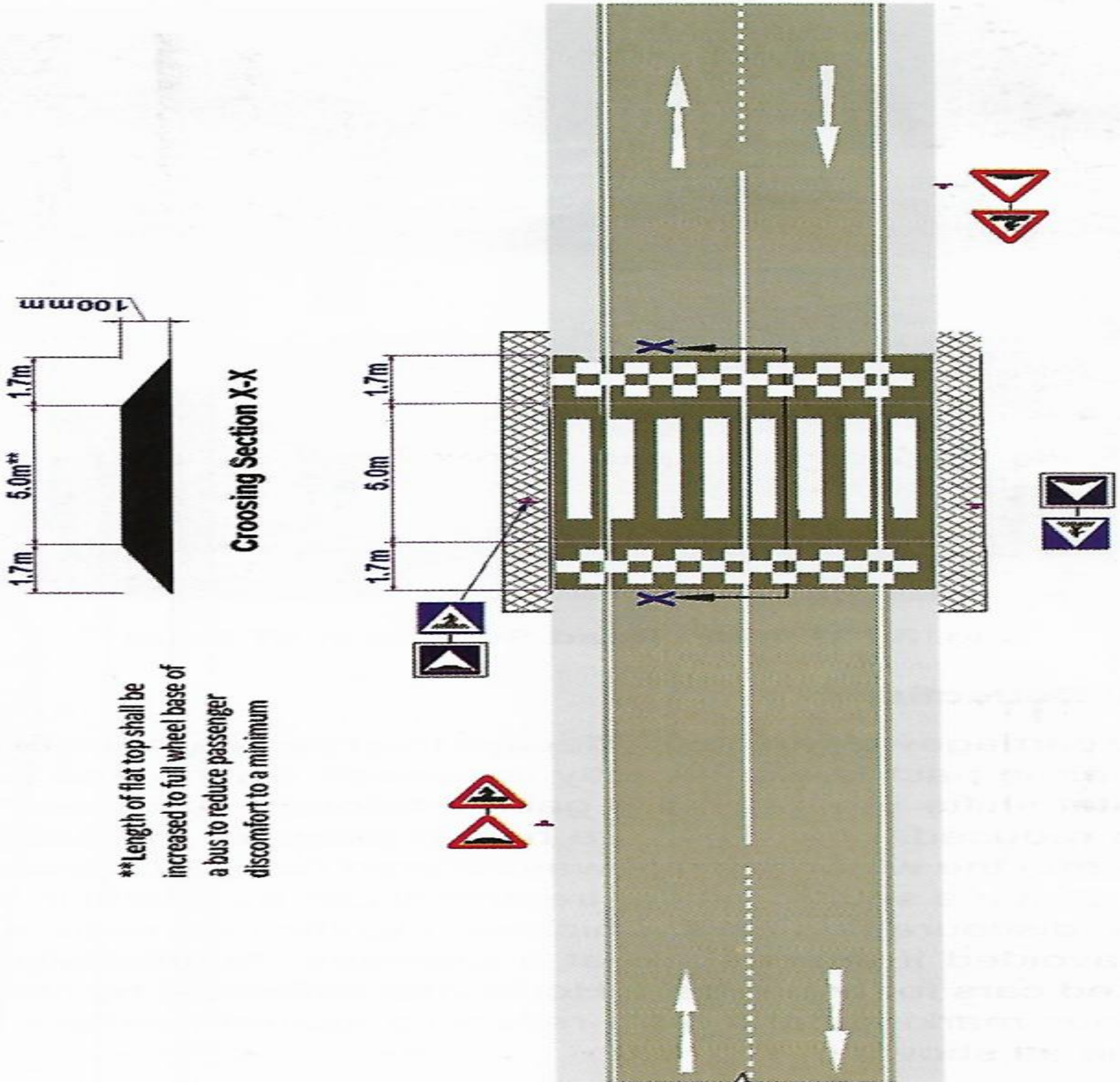


Fig. 2.6 Rumble Strip (Not to Scale)

Fig. 2.9 Speed Table



ig. 3.6 Geometric Details of Speed Table/Raised Pedestrian Crossing

Speed Cushions

Allow trucks and emergency vehicles to bypass hump.

If improperly designed allow regular vehicles to avoid.

Not as effective as full width humps for reducing speed

Raised Intersections

Raised Crosswalks

Horizontal Deflections

- Horizontal shifts in carriageway are less effective than vertical ones in achieving reduction in speed.
- Essentially all horizontal shifts may be classified as chicanes
- Chicanes significantly reduce parking spaces and should be avoided if spaces are at a premium

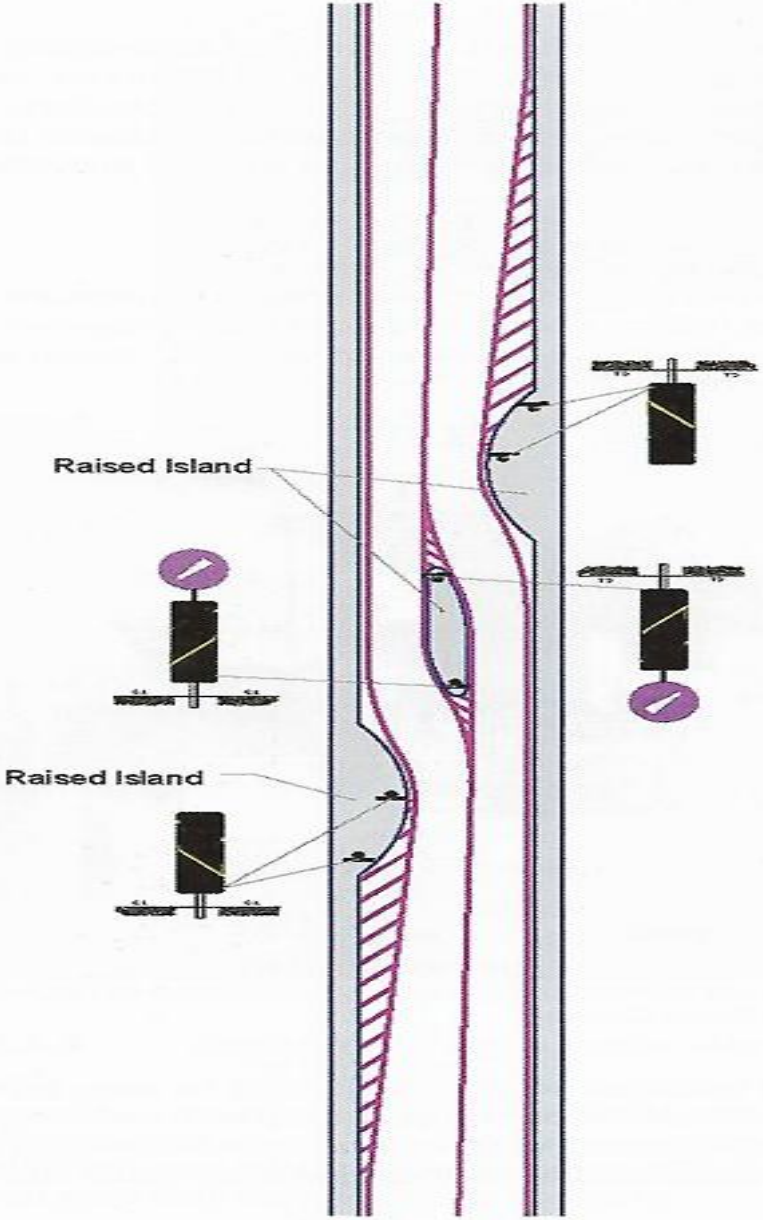


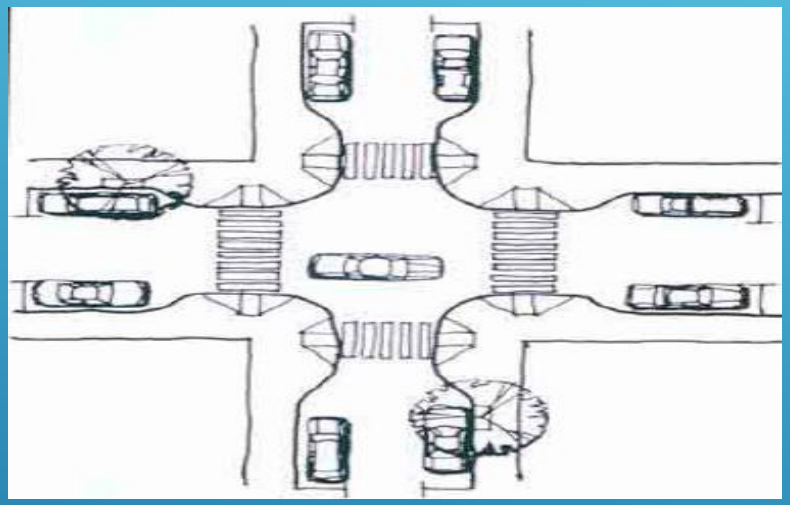
Fig. 3.8 Chicane Island to Deflect the Traffic

Road Narrowing

- Road Narrowing may be considered as another supportive measure to vertical deflections.
- Extra space created by road narrowing is generally used to provide some combination of widened footways, dedicated cycle way and formalised parking bays.

Centre Island Narrowing

Curb Extensions



Central Islands

Have a limited effect on reducing speeds unless combined with another measure such as chicane. They do however provide useful pedestrian refuges

Traffic Circle

Fig. 2.15 Mini Roundabout in IIT Delhi

Physical Obstruction

Measures that prevent particular vehicular moments thereby discouraging or eliminating cut – through traffic

Full Closure

Half Closure

Median Closures

Gateway

Entrance treatment typically using physical and textural changes that provide identity to an area

Fig. 2.22 Entry Gate to Harvington Village near Evesham in Worcestershire, England

On Street Parking

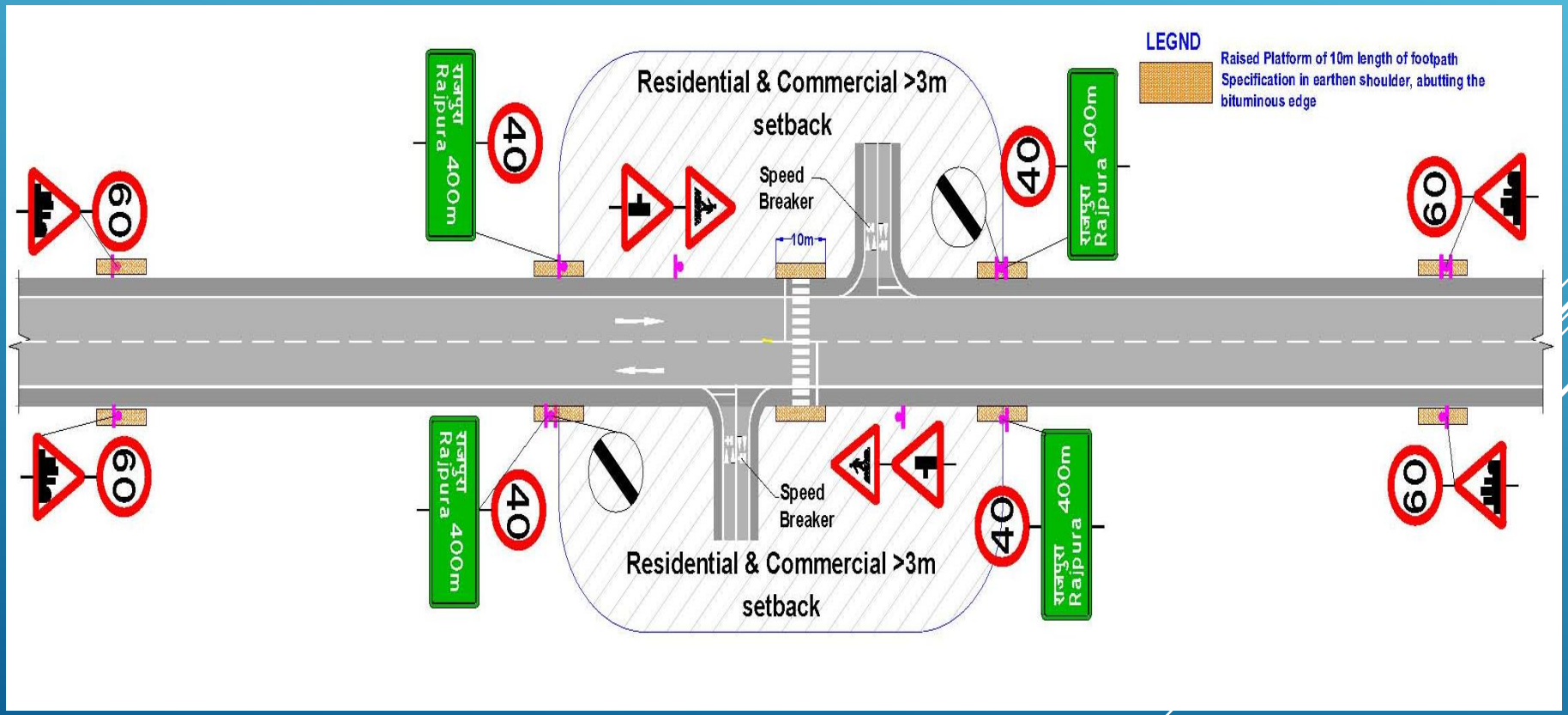
Provision of on street parking reduces roadway width and consequently reduces vehicular speeds.

Signs and Pavement Markings

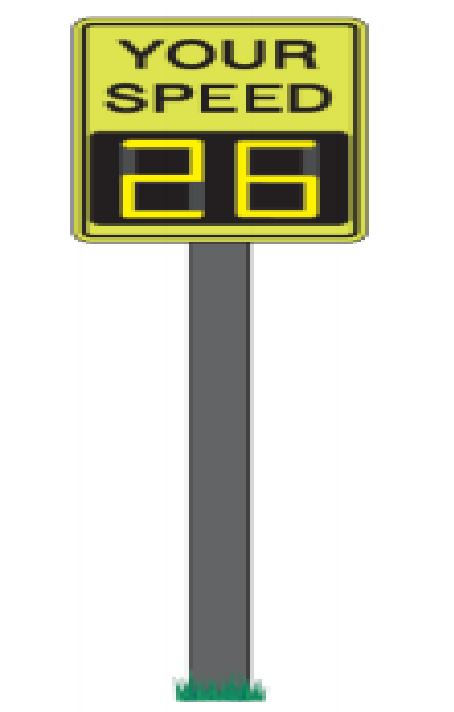
- Can be used as traffic calming measures that regulate traffic movement in lieu of physical changes to the roadway. In certain applications these measures may produce the same effect as physical traffic calming measures. However, police enforcement is often required to ensure motorist compliance.

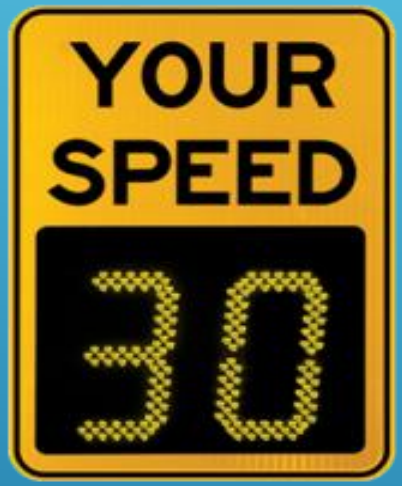
Influencing Driving Behavior

- Signs
- Markings
- Gates

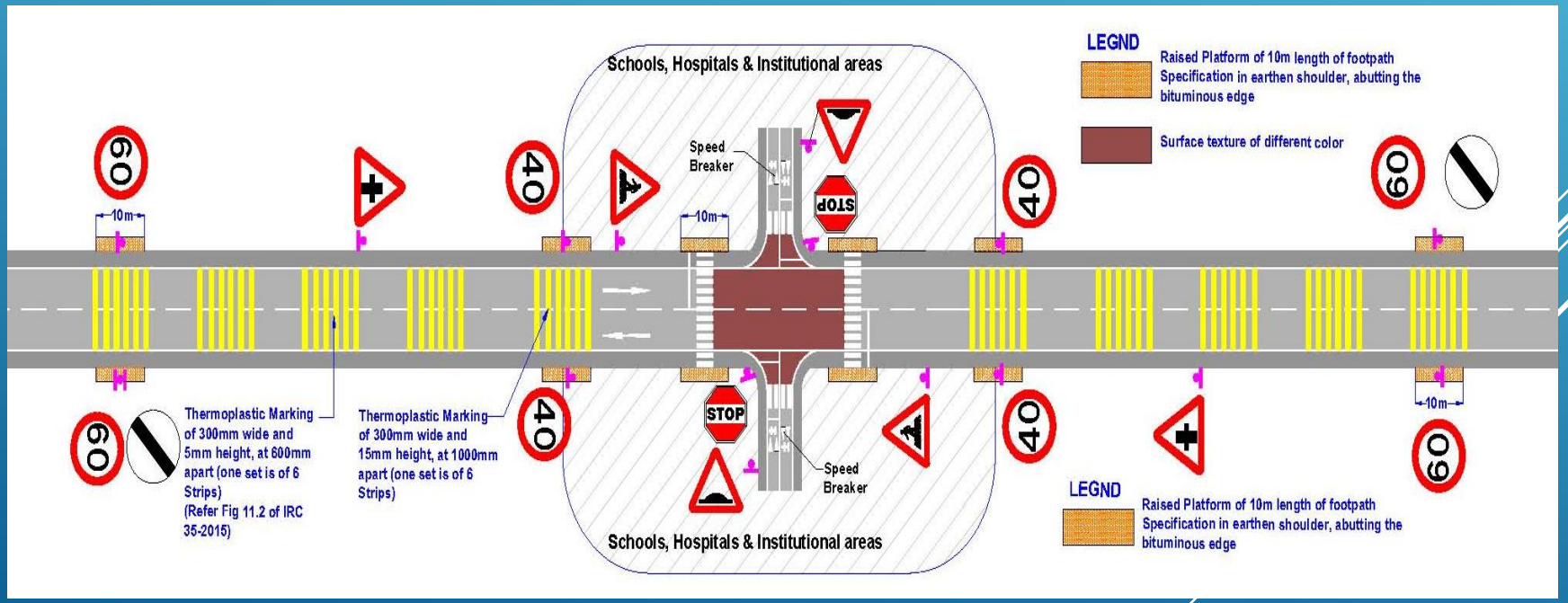


Feedback Signs



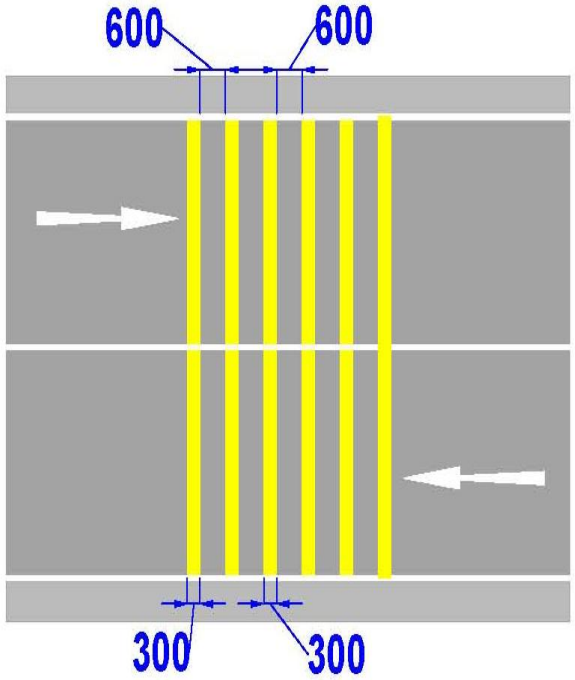


Textured Paving Over Raised Crossing



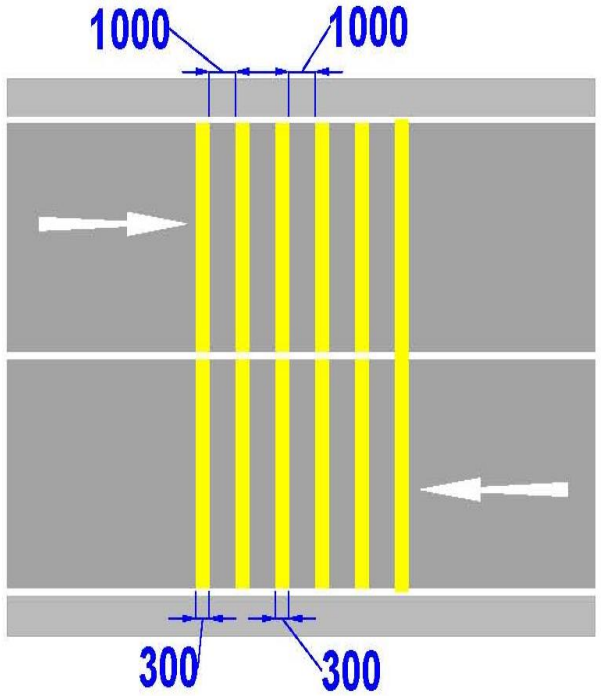
Uneven Road Surface

Thermoplastic Bar Markings



Thermoplastic Marking of 300mm wide and 5mm height, at 600mm apart (one set is of 6 Strips)

5mm height is achieved through two applications of thermoplastic, applied at an interval not less than 1 hour for the 1st layer to be solidified



Thermoplastic Marking of 300mm wide and 15mm height, at 1000mm apart (one set is of 6 Strips)

15mm height is achieved through six applications of thermoplastic, applied at an interval not less than 1 hour for the previous layer to be solidified

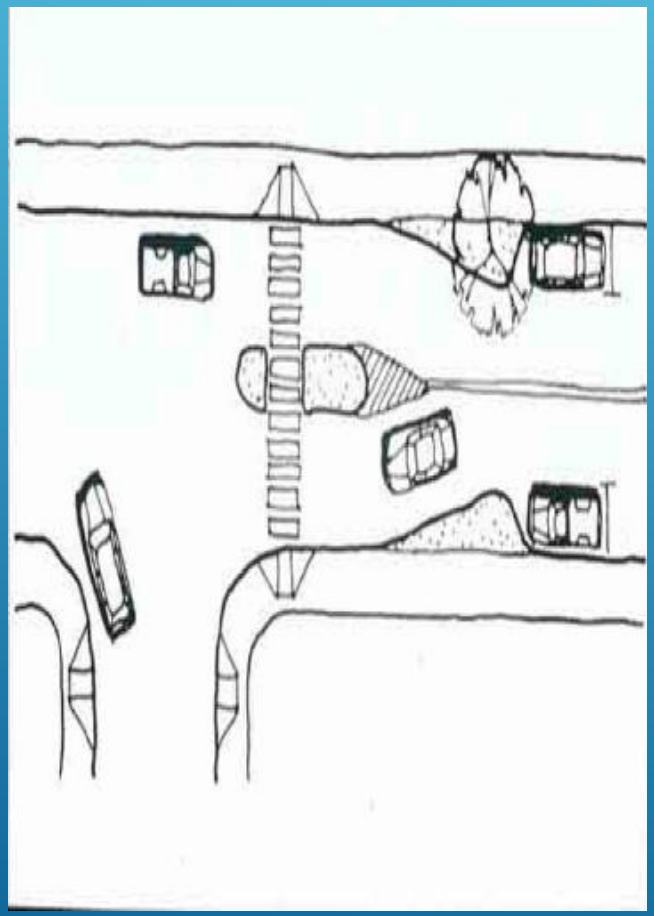
Miscellaneous Traffic Control Devices Used for Traffic Calming

- Traffic Cones
- Drums and Rope
- Box Junctions
- Central Refuges
- Lighted Traffic Bollards
- Reflective Devices
- Barricades

Combo – Speed Hump & Chicane

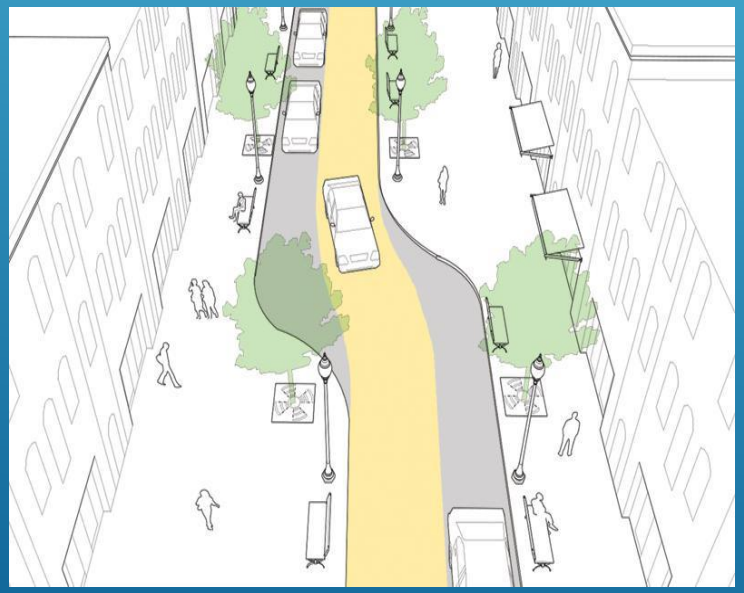
Parking Bump out Create Chicane

Speed Table Combined with a Choker



Horizontal Deflections

- Staggering - horizontal deviation of vehicles on the road, restricting them to known turning radii at different speeds for different vehicle types.
- Chicanes



Horizontal Deflections

Mini-Roundabouts

Effective solution for residential areas with single carriageway roads where the vehicle speeds should not exceed 30 km/h

Traffic Calming on Rural Highways

- NH & SH carry more than 70 percent of total traffic
- Safety is major concern especially when they pass through villages and towns
- Upgrading of NH/SH for swift movement must be balanced with safe environment for vulnerable road users

Demarcation of Zones for Traffic Calming Measures

- Area where NH/SH pass through villages have scattered patterns of development and low/erratic level of pedestrian crossing
- Need to gradually slow down the traffic as they come near

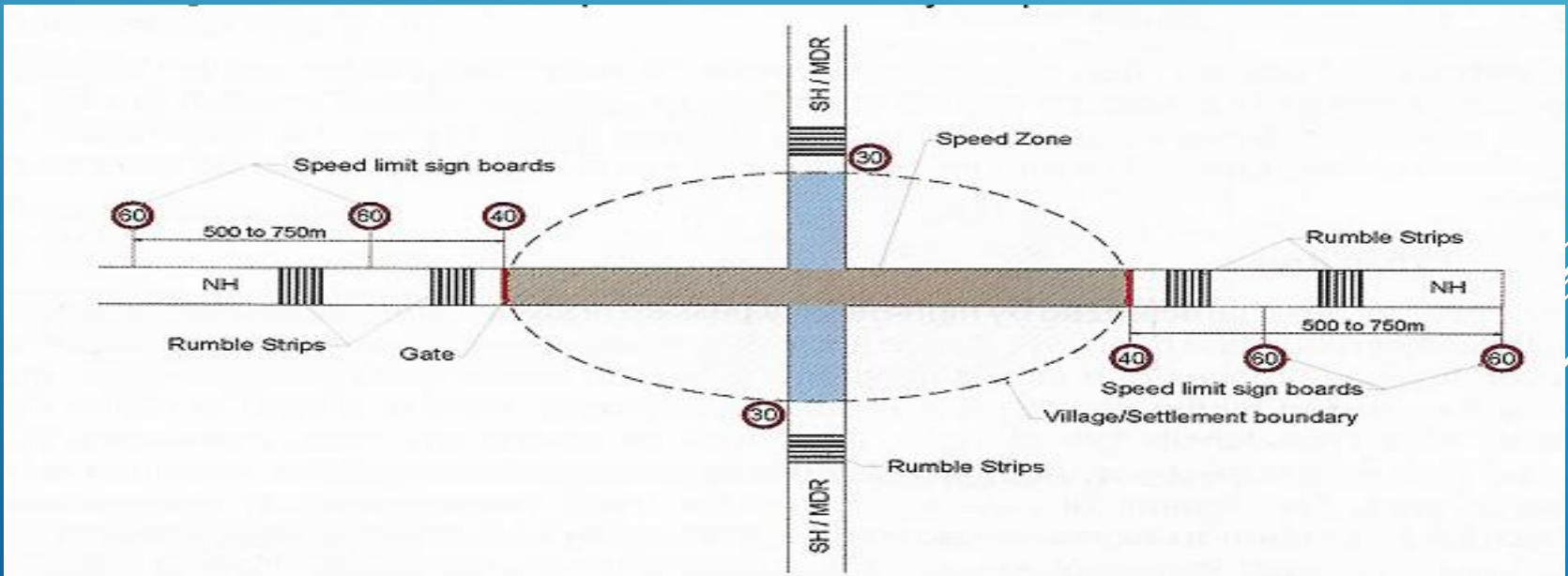


Fig. 4.1 Speed Zones on NH/SH Passing through Village

Demarcation of Traffic Calming Zones at Road Junctions

- In case of minor roads joining the highway not financially feasible to provide a signalised intersection.
- Often yellow or red warning lights are not respected by fast through traffic on low volume roads.
- Traffic calming measures at junctions (NH - SH, NH – ODR etc) should be recommended in context of appropriate road hierarchy.

NH / SH Meeting NH

- This would be major intersection and an interchange point both either traffic police & signals installed to control traffic flow.
- Advisable to treat minor road with adequate traffic calming measures.
- Area of influence on main road needs to be demarcated for appropriate treatment to reduce speed to acceptable limits.

MDR Meeting NH / SH

- Such roads usually connect important villages village mandis.
- Often they are unmanned and rarely signalised.
- Traffic Calming measures to be installed on minor road.
- Major road should also be treated visually to sensitise drivers about approaching traffic.

ODR Meeting NH / SH

- Such junctions more vulnerable to conflicts.
- Having a low traffic volume on minor road results in fewer activities at intersection.
- Such junctions thus remain inconspicuous from a distance on major road.
- Vehicles approaching from minor road need to slow down to “dead speed” before they can find gaps on major road.
- Measures on major road would include visual warnings on major road with rumble strips and speed breakers on minor road.

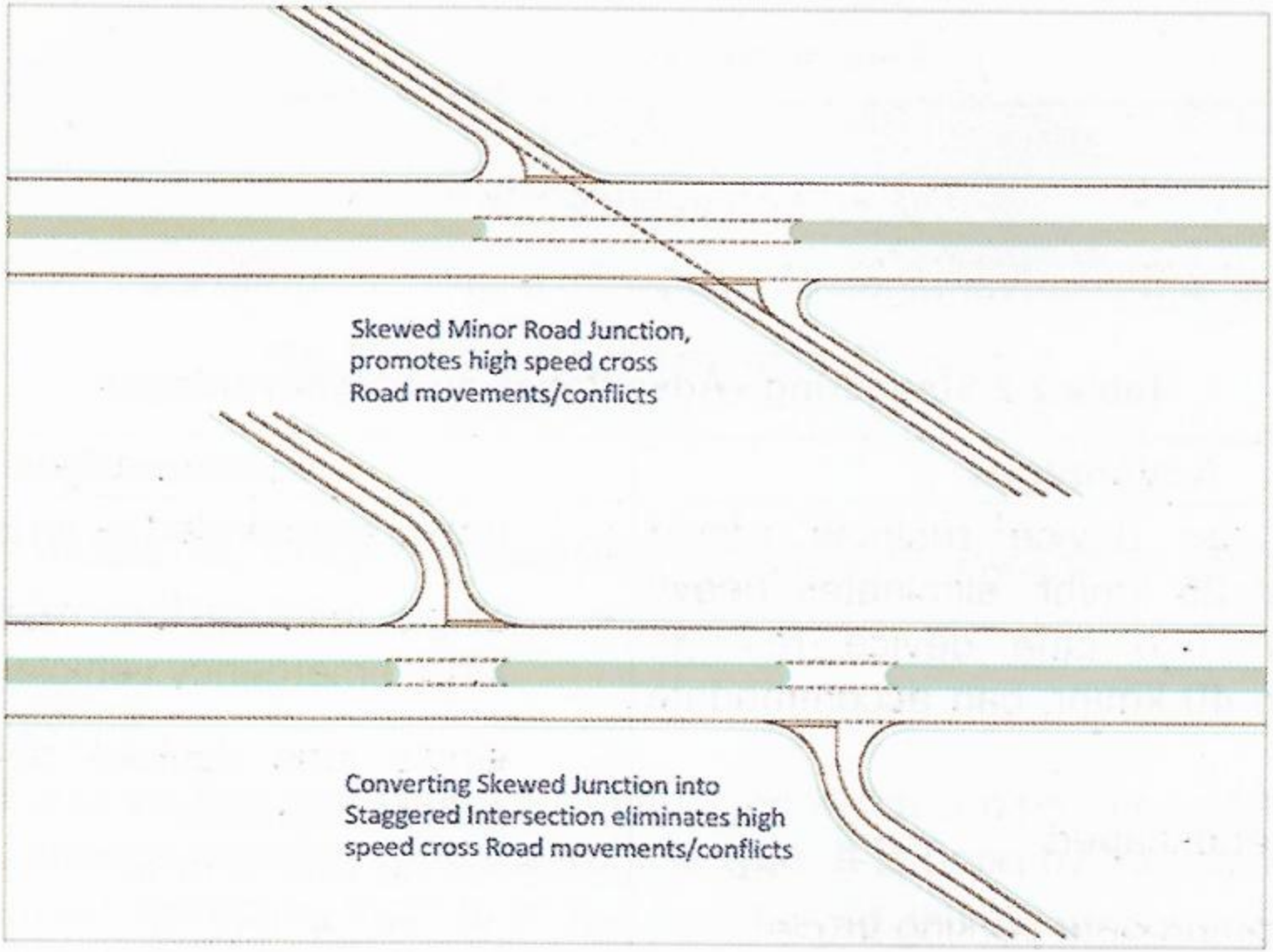
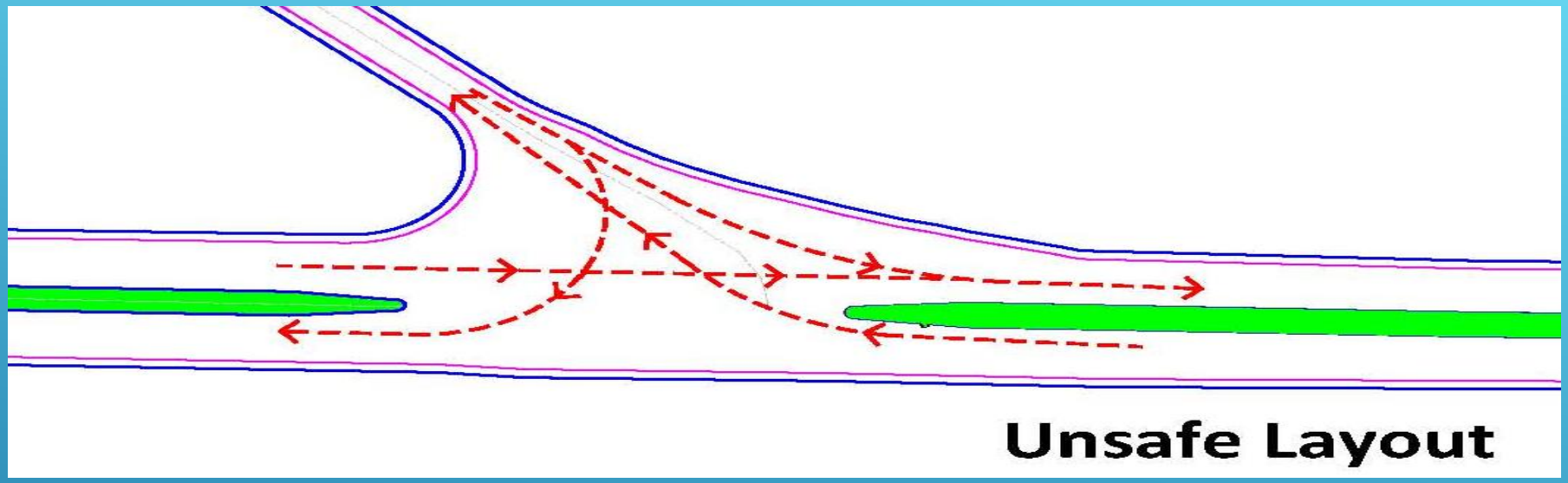
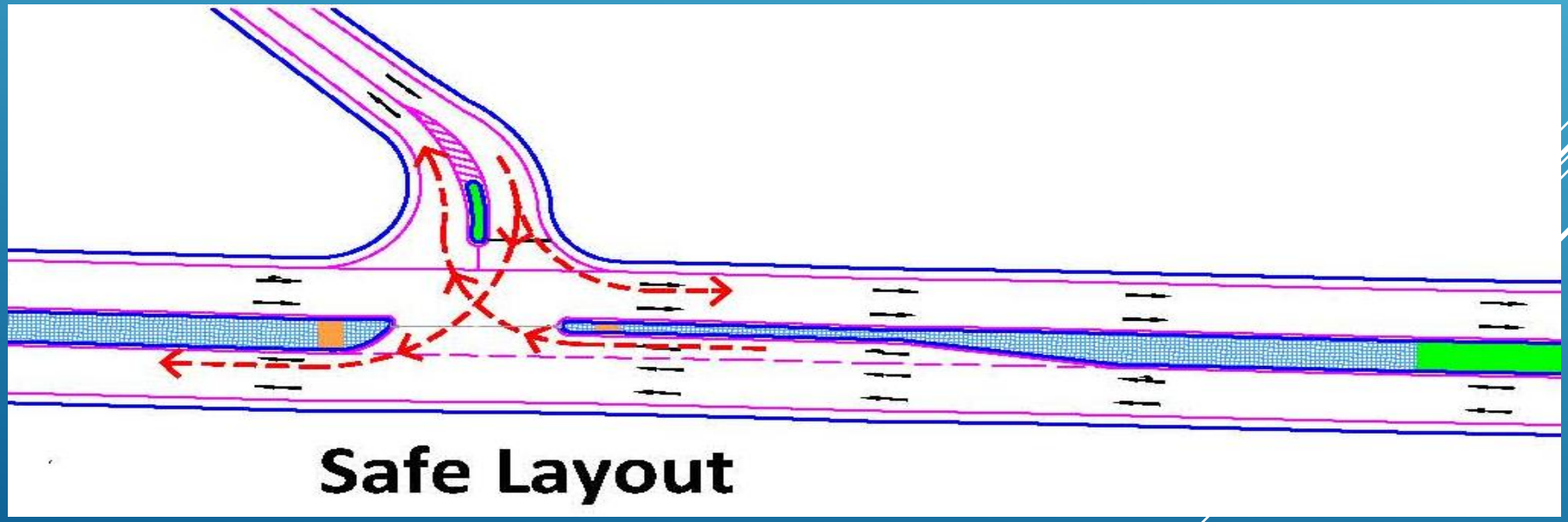


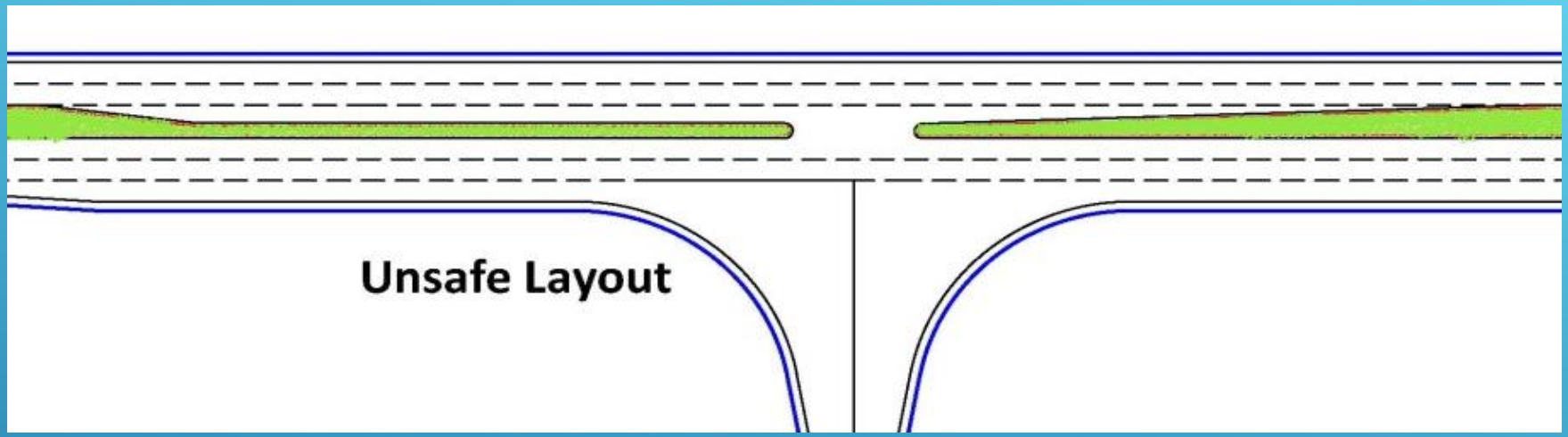
Fig. 2.19 Staggering of Side Roads

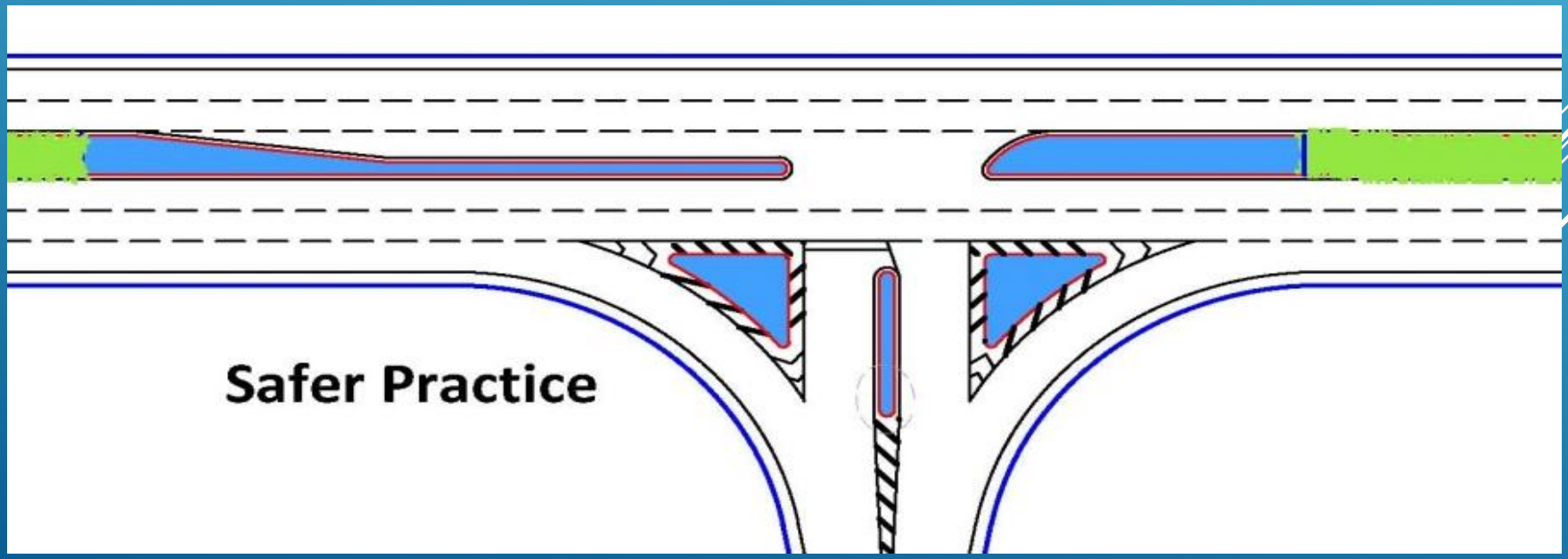
Geometric elements in Priority Junction



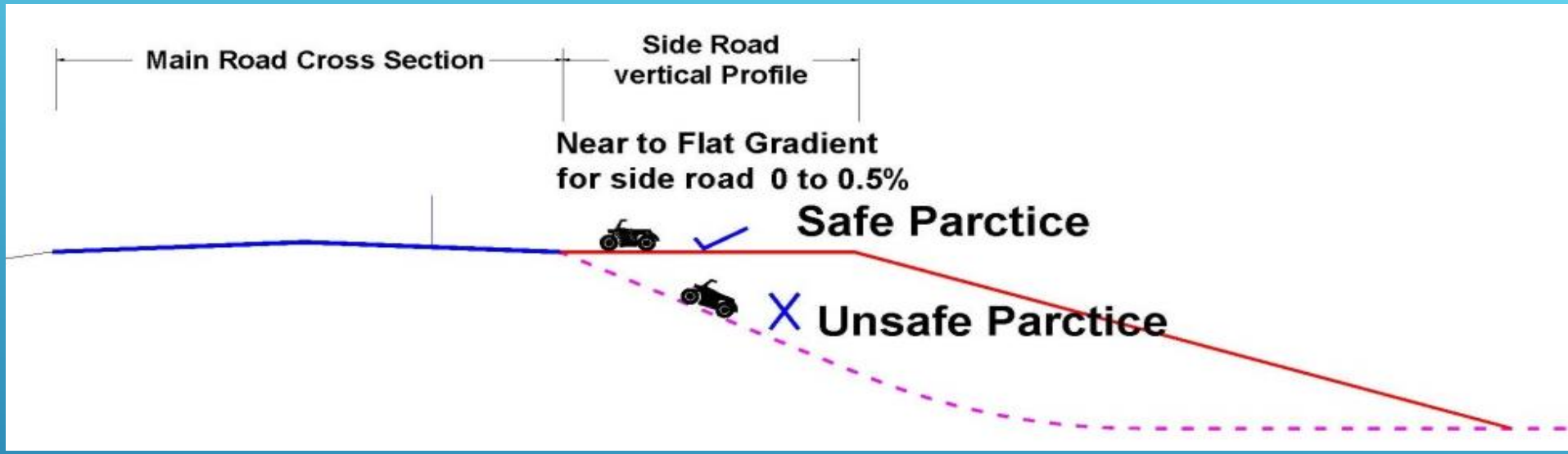


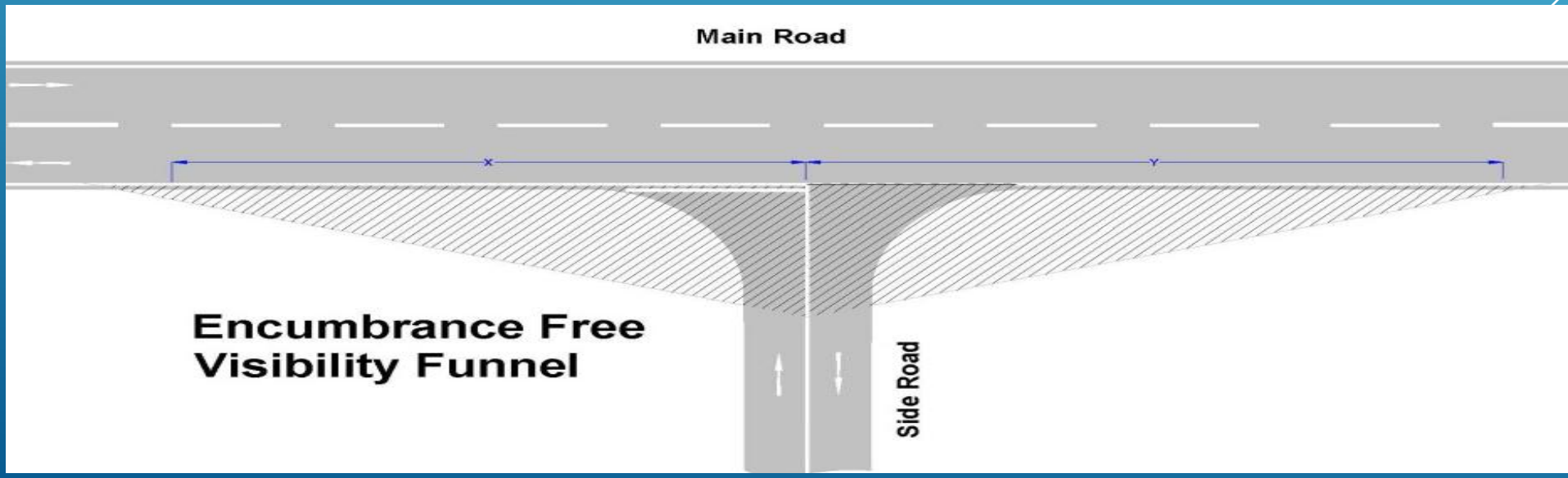
Geometric elements in Priority Junction





Geometric elements in Priority Junction





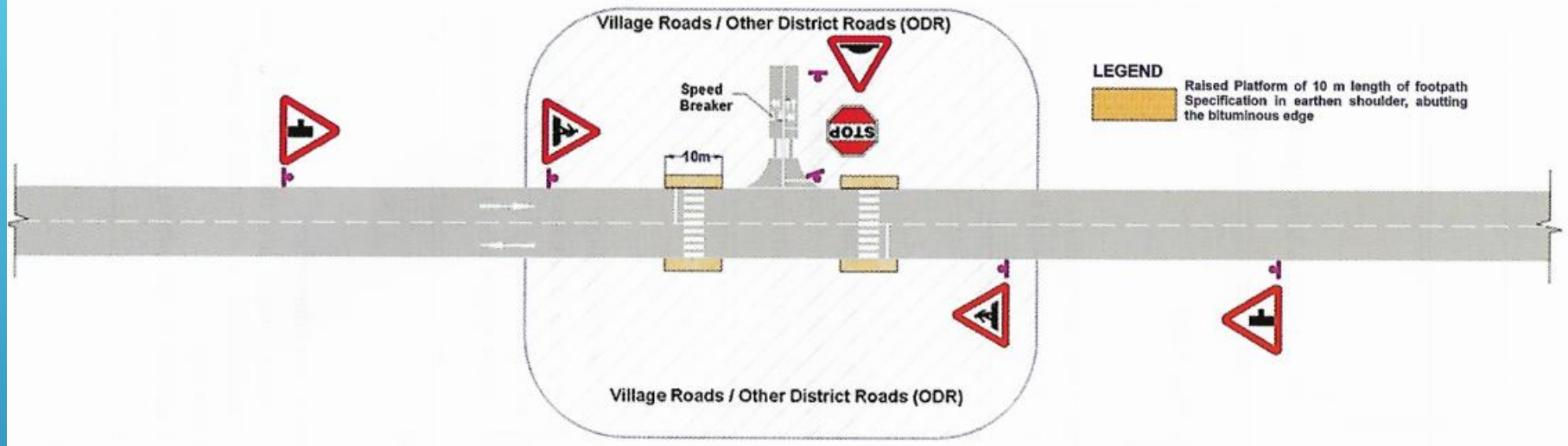


Fig. 5.19 Schematic Diagram - Road Junctions on Highways (a)

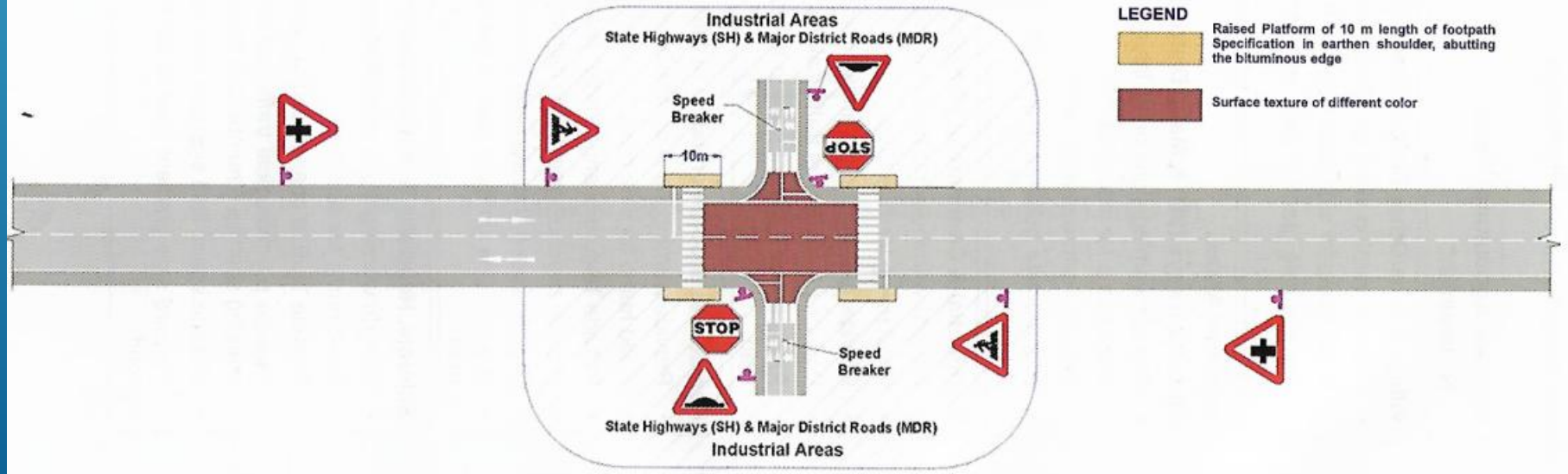


Fig. 5.20 Schematic Diagram - Road Junctions on Highways (b)

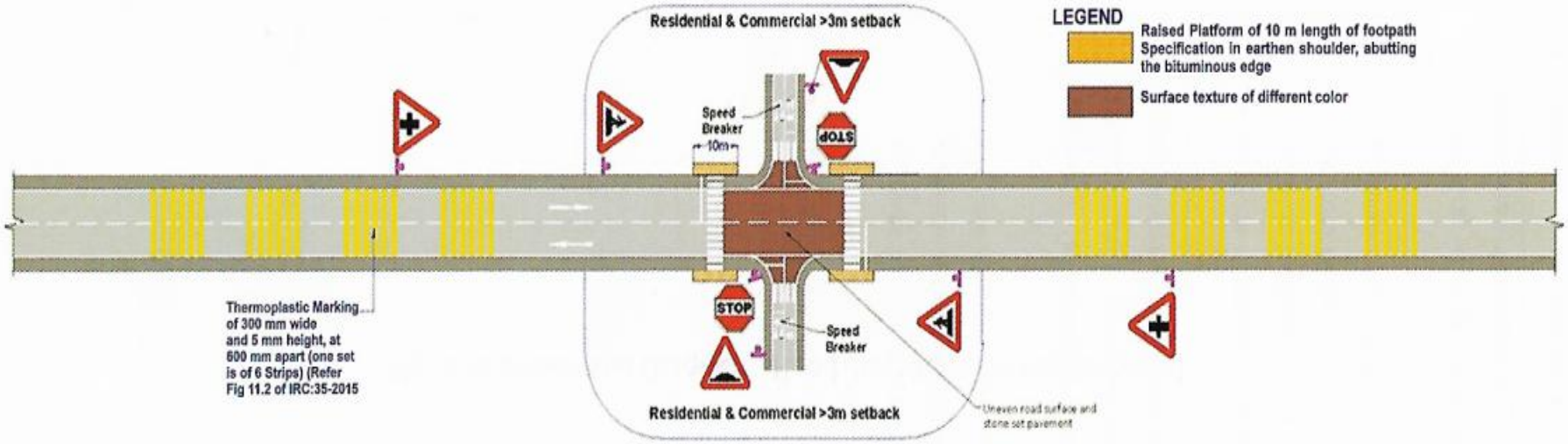


Fig. 5.21 Schematic Diagram - Road Junctions on Highways (c)

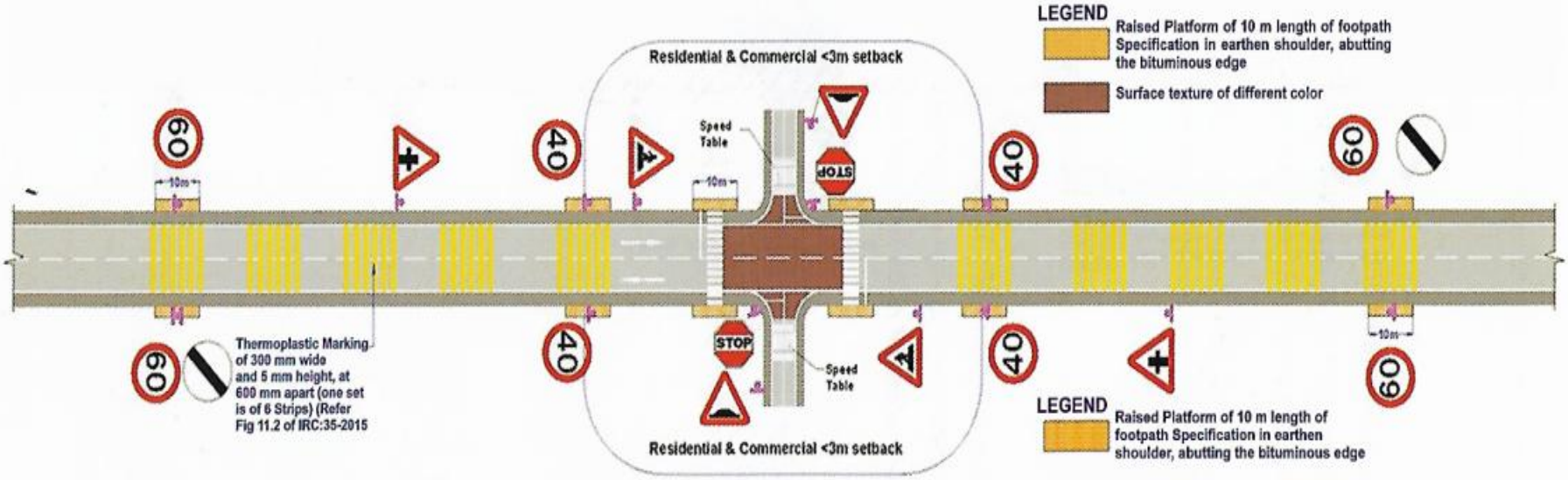


Fig. 5.22 Schematic Diagram - Road Junctions on Highways (d)

Checklists for Traffic Calming Treatment

- Treatment on NH / SH corridors passing through towns / villages dependent upon.
- Variation in day time and night time traffic volume.
- Variation in local traffic activities in day time and night time.
- Day time speeds vs night time speeds.
- Local needs of pedestrian crossings.

Traffic Calming Treatment of Rail - Road

- Highway traffic approaching intersection be warned using 30 km / hr speed limit signs “rail road crossing ahead” warning sign as well by bright street lighting at the intersection and physically using rumble strips on both sides of crossing.
- In case of undivided highways, a 100 to 200 m long mountable median should be provided on both sides of crossing.

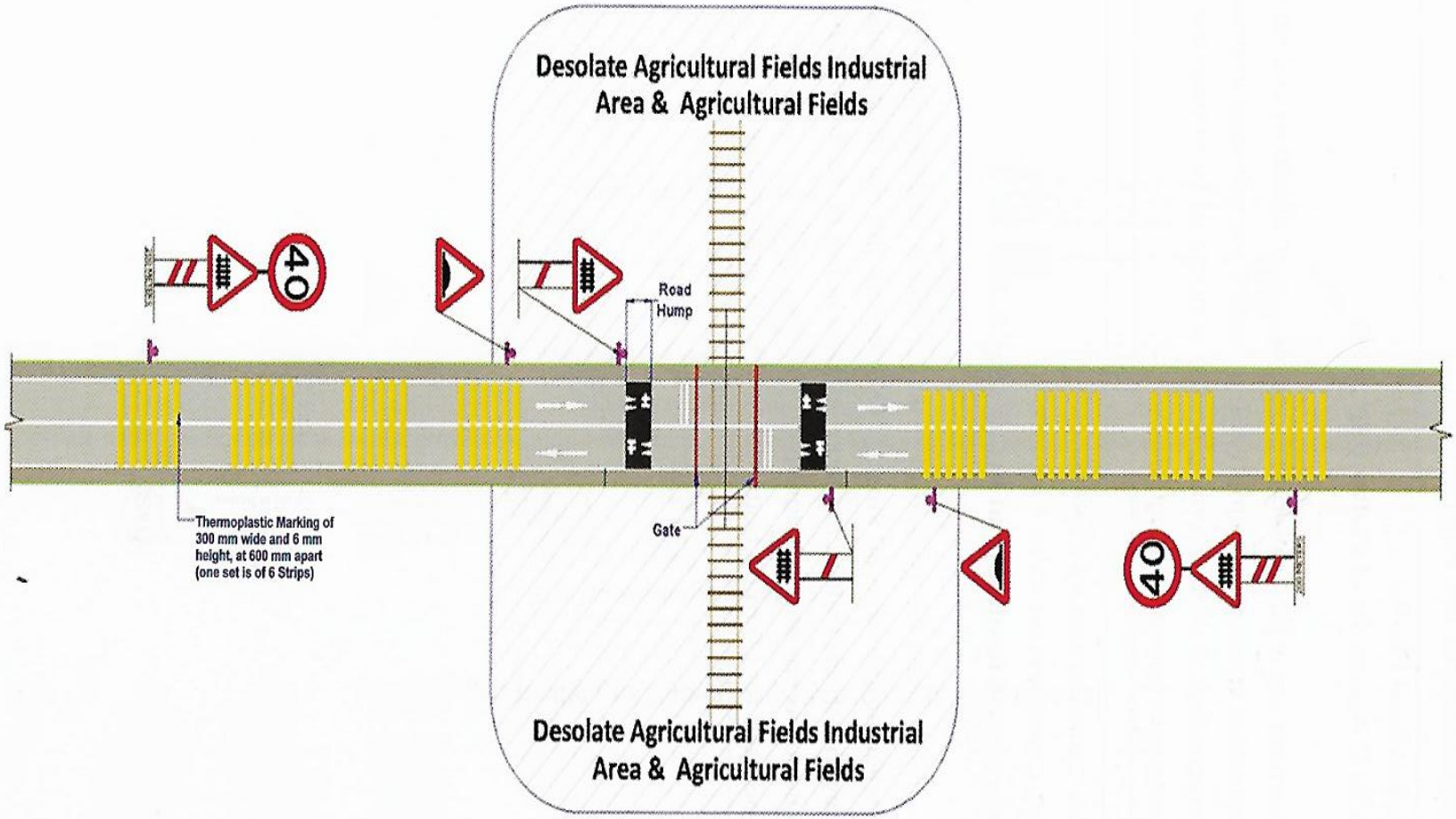
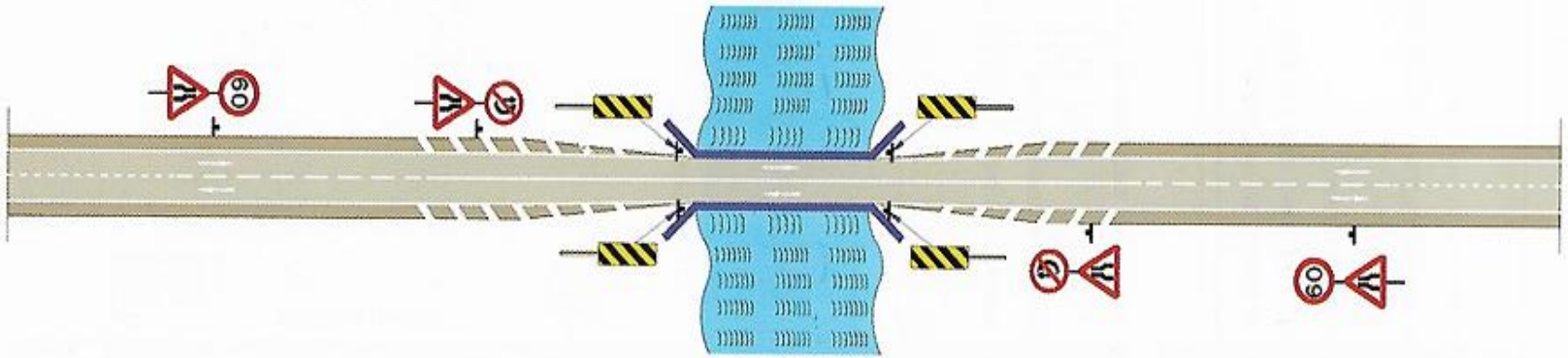


Fig. 5.24 Schematic Diagram - Railroad Intersections on Highways (a)

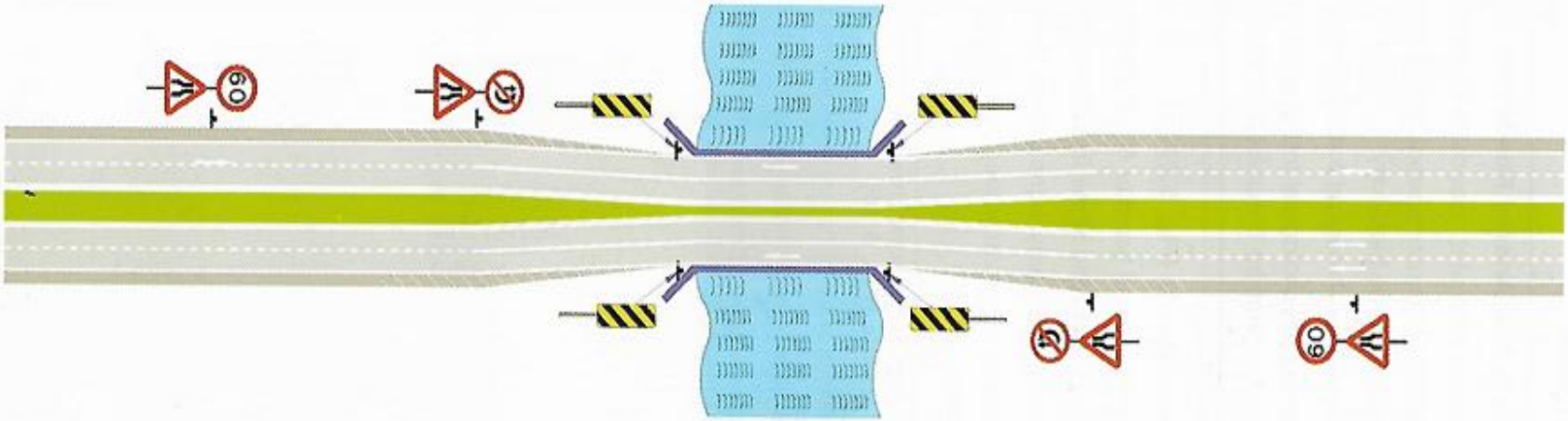
Traffic Calming Treatment of Bridges on Highways

- Highway traffic approaching bridges on highway should be warned through signposts indicating “Bridge Ahead”.
- Speed limit of 50 km / hr.
- No overtaking zone.
- Rumble strips should be used to physically warn the drivers.
- Reflective studs should be used to highlight lane markings on the bridge.



2 Lane Bridges (With No Footpath)

Fig. 5.26 Schematic Diagram - Bridges on Highways (a)



4 Lane Bridges (Only Carriageway)

Fig. 5.27 Schematic Diagram - Bridges on Highways (b)

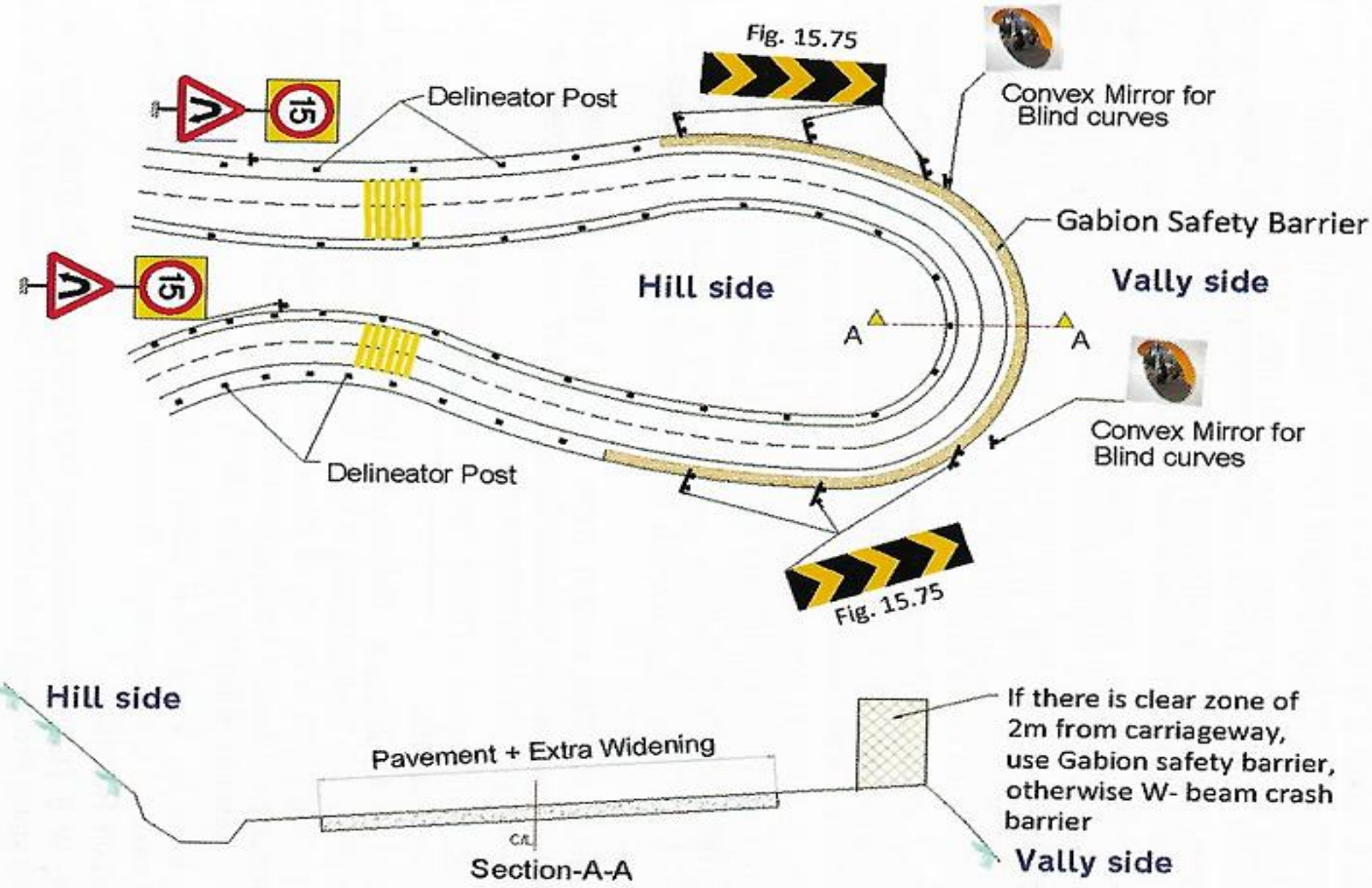
Traffic Calming on Hill Roads (for Normal & Steeps drops / climbs)

Normal Drops or Climbs

Fig. 5.31 Schematic Diagram - Hill Roads (a)

Normal Drops or Climbs

Fig. 5.32 Schematic Diagram - Hill Roads (b)



Hairpin Bend

Fig. 5.33 Schematic Diagram - Hill Roads (c)

Effectiveness of Traffic Calming Measures

- Speed Reduction
- Accident Reduction
- Noise Reduction
- Air Pollution Reduction

Expected Speed Reduction and effect of various Traffic Calming Measures

	Upper limit of maximum speed (kph)		Upper limit of 85 percentile speed (kph)		Range of average speed (kph)	
	Before	After	Before	After	Before	After
Vertical shifts in the carriageway	100	40	75	30	45-65	18-25
Lateral shifts in the carriageway	100	65	75	45	45-65	22-35
Road narrowing to a single lane	100	65	75	45	45-65	22-35
Roundabout	100	65	75	45	45-65	22-35
Road narrowing to a reduced width	100	95	75	70	45-65	40-55
Central Islands	100	95	75	70	45-65	40-55

A recent survey of 35 British calming schemes, with the majority including vertical shifts in the carriageway, found that the average reduction in the 85 percentile speed was 16kph [6].

Impacts of Traffic Calming on Noise Levels

Measure	Usual Level	Peak Level
None (unobstructed traffic)	68-69	72 DB
4-Way Stop	66-67	69
Traffic Circle	60-64	70
Raised Crossing	60-62	64

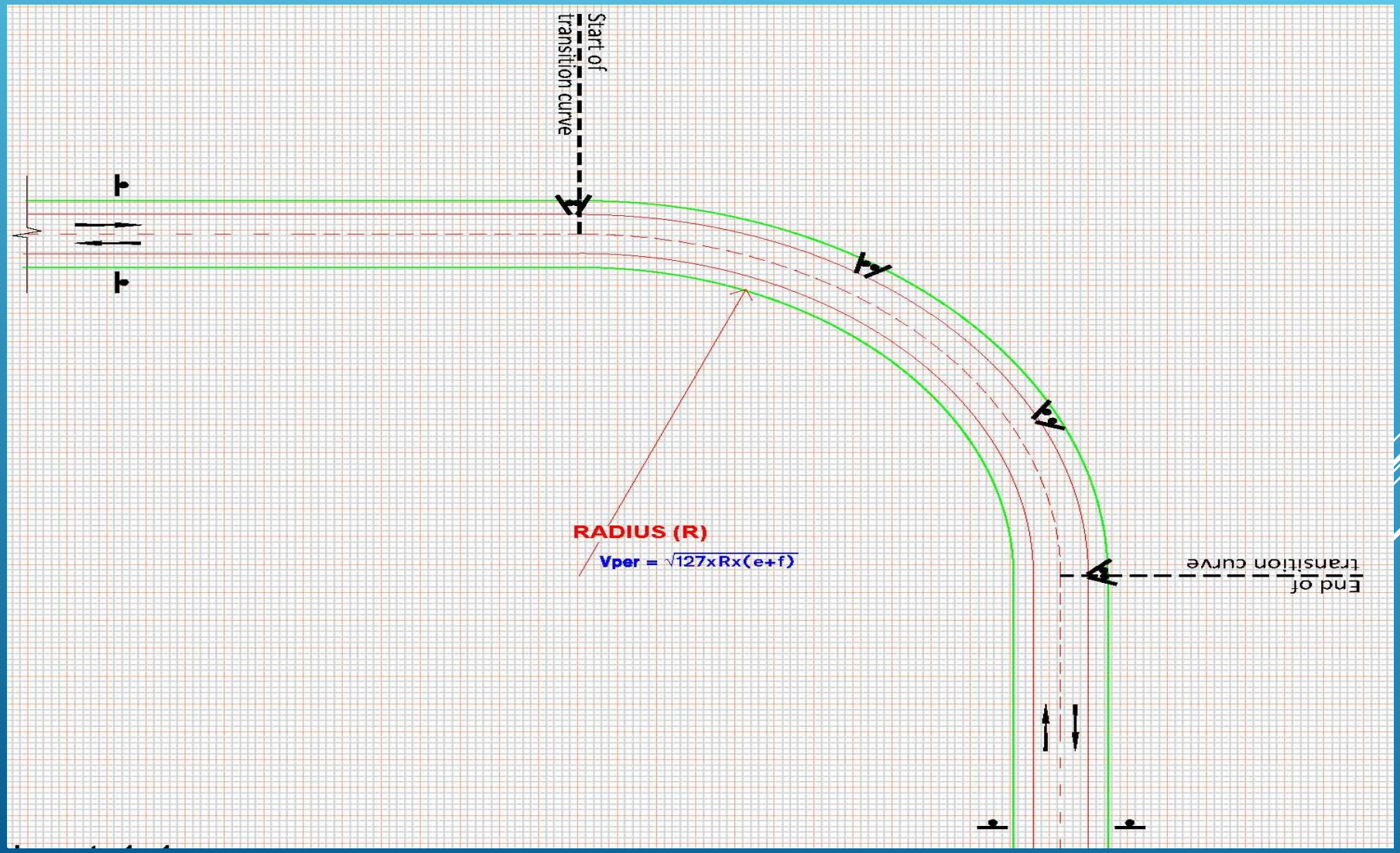
IRC:99-2018

GUIDELINES FOR TRAFFIC CALMING MEASURES IN URBAN AND RURAL AREAS

(First Revision)

INDIAN ROADS CONGRESS
2018

Practical Exercise 1 : The curve shown below witnessing many fatal ran off accidents. Develop appropriate safety measures to prevent such accidents by providing Psychological traffic Calming Measures with Transverse Bar Marking given in IRC 99 2018.



3.7 Traffic Calming on Main Roads

In a main road, changes in (surface) level are often regarded as unacceptable, thereby eliminating the use of vertical shifts. Without vertical shift, the potential for achieving slower traffic and reduction in accidents is significantly reduced. Transverse bar marking an alternative in such main road, where vertical deflection might lead to speed breaker hit accidents. **Fig. 3.14** gives alternatives with traverse bar markings of 5 mm and **Fig. 3.15** with transverse bar marking of 15 mm at the boundary of speed zone. Since bar marking with 15 mm demands speed reduction, a set of "SLOW" marking shall be given immediately before markings, at 20 m and 40 m from bar marking.

Approach Speed (Kmph)	Bar Marking (Number of TM08)	Distance (d1, d2, d3 & d4) from Hazard
Upto 50 km	1 set	d1=50,
51 to 65	2 set	D1=50, d2=80
66 to 80 kmph	3 set	D1=50 m, d2=80 m, d3=120 m
81 to 100 kmph	4 set	D1=50, d2=80, d3=120, d4=180 m

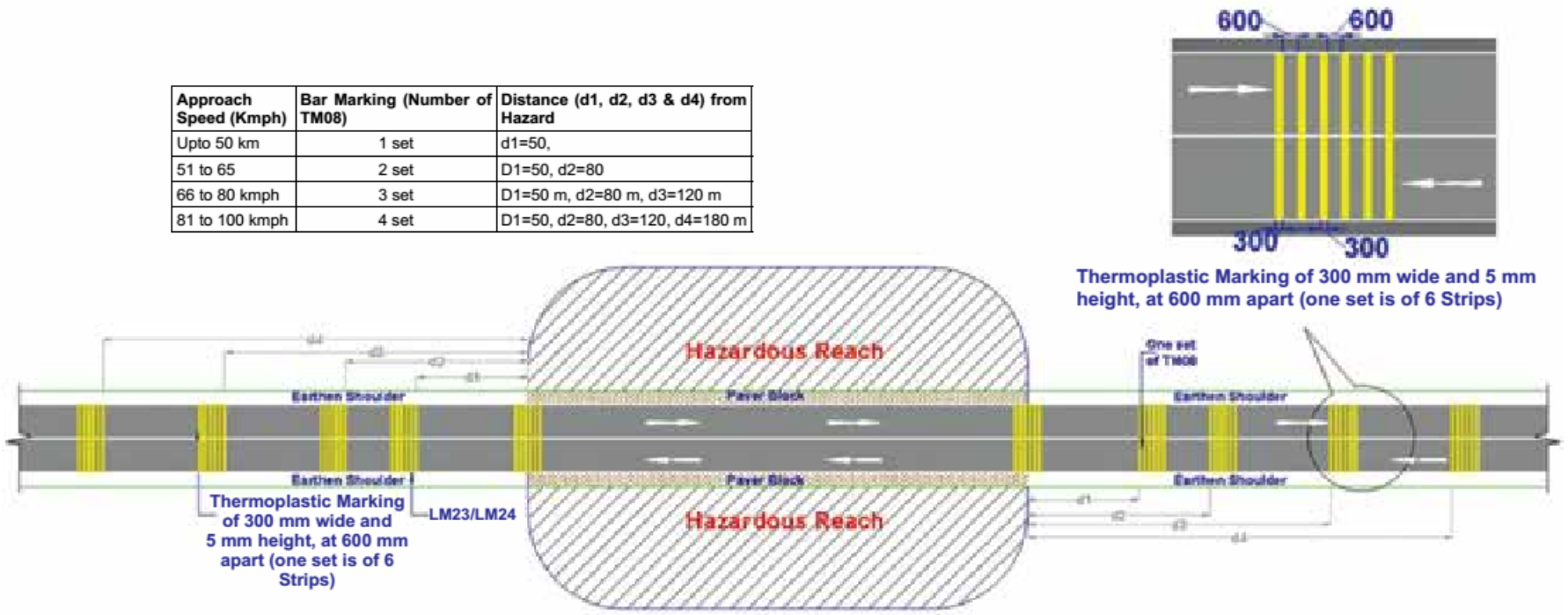


Fig. 3.14 Transverse Bar Marking as an Alerting Measure

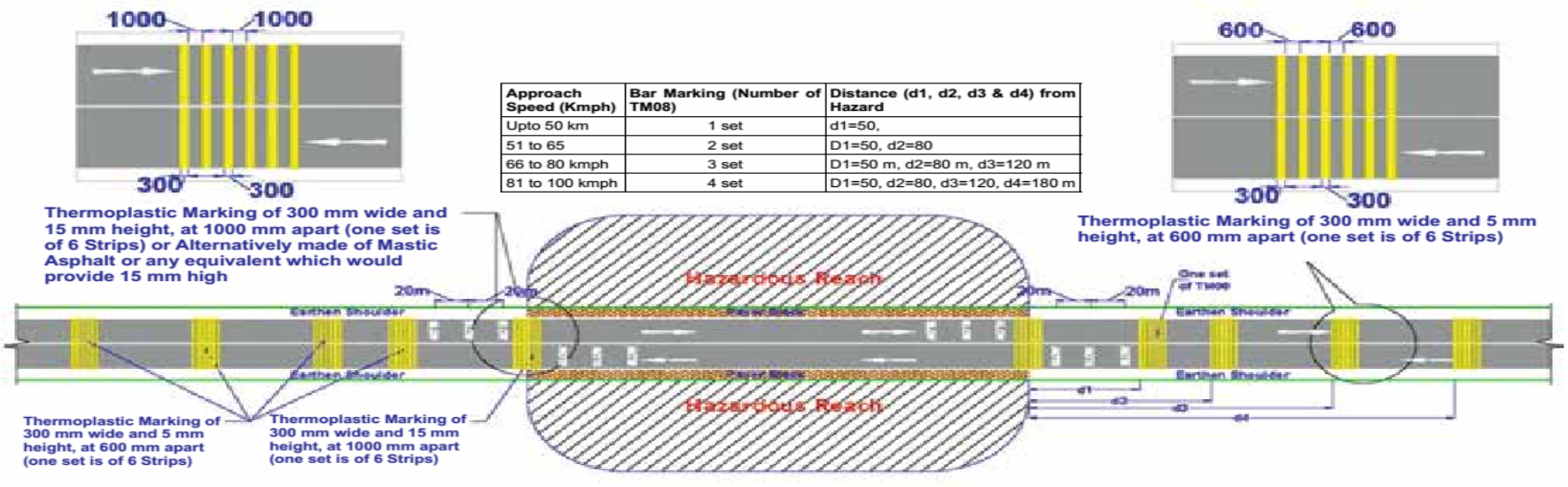


Fig. 3.15 Transverse Bar Marking with Stricter Compliance

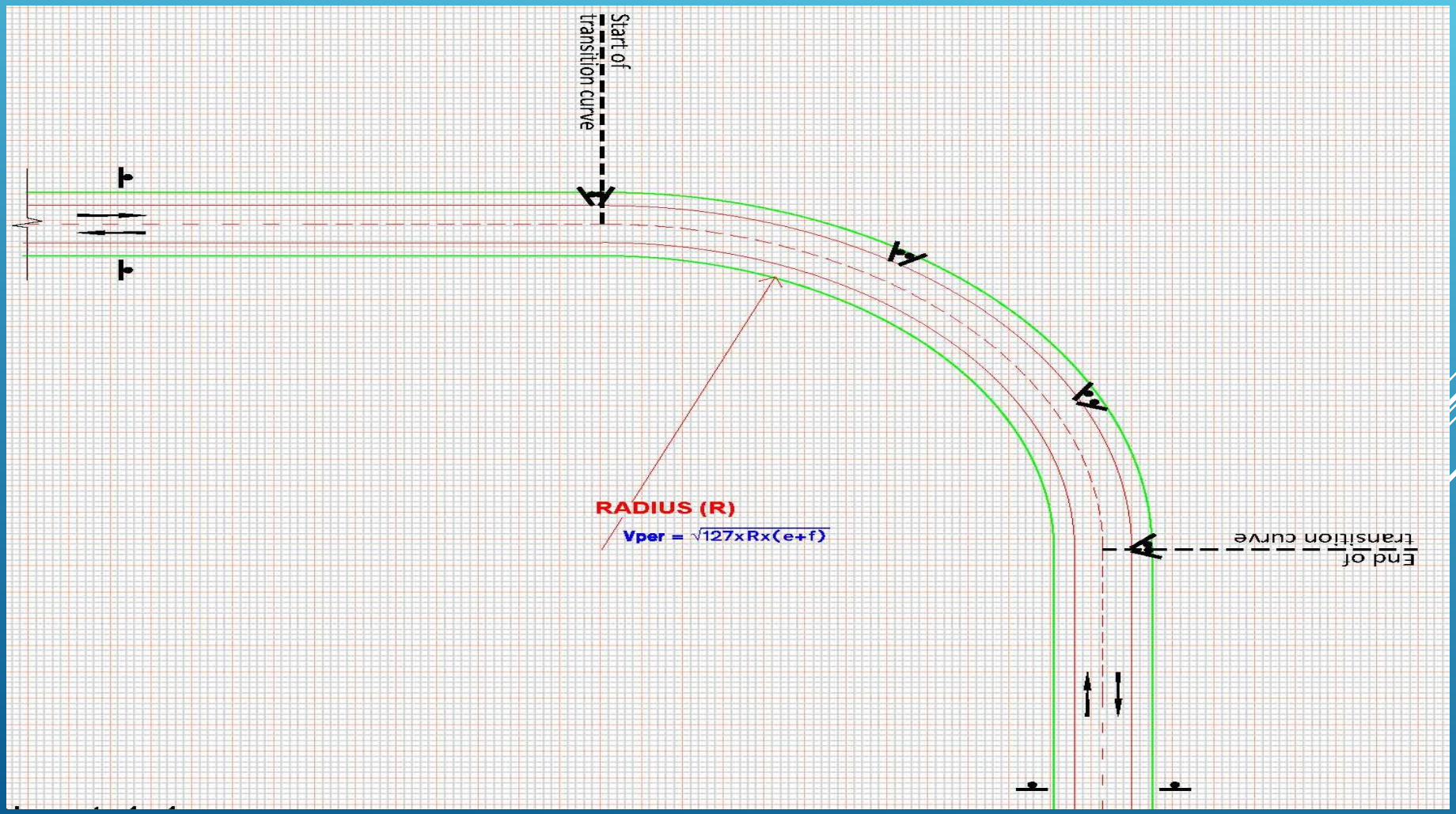
Common techniques employed on main roads in urban areas include:

- Road narrowing
- Islands
- Tree planting

Techniques used to control traffic using traffic signals include holding back traffic on a radial to avoid saturating downstream junctions. Applying this technique to a main radial as part of an area wide traffic calming scheme could be used to reduce queuing along the calmed length of road. Physical speed reducing measures would be required to prevent traffic from speeding up once the restraining effect of the congestion was removed. In addition, this technique may increase rat running.

When signaled junctions are relatively close together they may be linked to provide a “green wave” for main traffic movements. This linking may also be used to achieve a “calm” driving speed of 40 km/h. Drivers exceeding the linking speed would hit a red light and would have to wait for the other traffic to catch up. Regular road users would soon realize the benefits of driving at the appropriate linking speed.

Practical Exercise 2: The curve shown below witnessing many fatal ran off accidents. Develop appropriate safety measures to prevent such accidents by providing Physical traffic Calming Measures given in IRC 99 2018, in a situation where Transverse Bar Marking alone is not yielding required speed reduction.



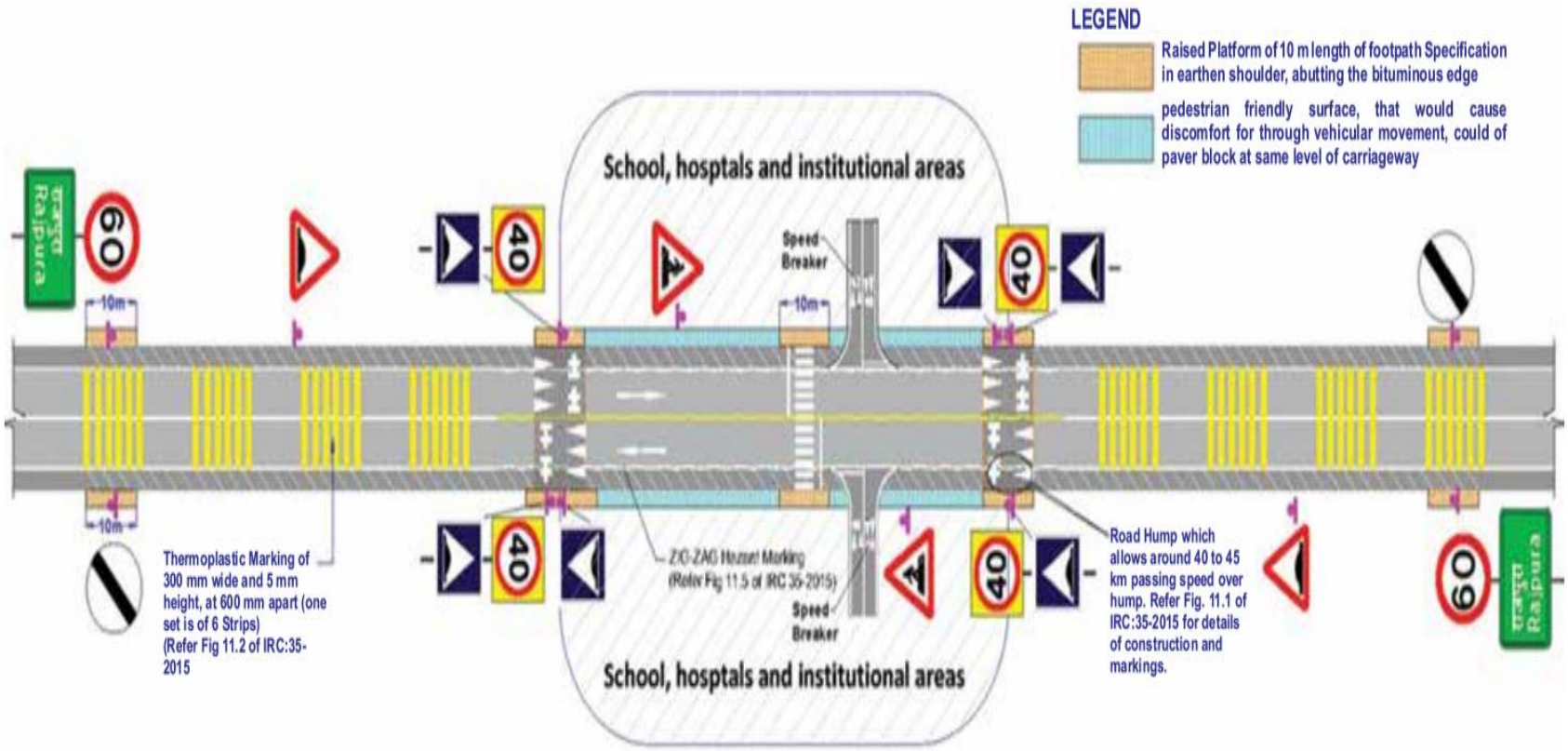


Fig. 5.10 Schematic Diagram for Highway Corridors without Central Medians (e)

3 TRAFFIC CALMING MEASURES IN URBAN AREAS

Traffic calming can help create more attractive urban environments. Commercial areas along higher-speed streets tend to be unattractive, as much land is used for parking, and settlement patterns have no clear form. Traffic calming projects can even reduce the amount of land devoted to streets and parking, which in turn can increase green-space and reduce impervious surfaces, resulting environmental and financial benefits. Traffic calming schemes generally incorporate a wide range of measures designed to complement each other in both speed reduction and environmental terms. Schemes are designed to be self-enforcing, although the effectiveness of this varies according to the measures employed. The principle techniques used fall into four areas:

- Vertical Deflections
- Horizontal Deflections
- Road Narrowing
- Central Islands

The effects of these measures may be reinforced by a range of supporting measures.

3.1 Vertical Deflections

Vertical shifts in the carriageway are the most effective and reliable of the speed reduction measures. Some of the techniques available to achieve this include:

- Speed Breaker
- Speed Bumps
- Speed Table
- Uneven Road Surface and Stone Set Pavement

3.1.1 *Speed Breaker/Road Hump*

Speed breaker may be of several varieties, the rounded and flat topped being the most common. The latter are particularly suitable in providing crossing places for pedestrians. The width of humps may be restricted to allow the longitudinal drainage. Speed breaker are not recommended on bus routes because of the discomfort caused to passengers.

3.1.1.1 Circular Hump

The profile of circular shaped hump is based on the shape of a circular arc with a radius varying from 11 m to 113 m and a chord length varying from 3.0 m to 9.5 m to achieve desired speed of 20 km/h to 50 km/h. Circular shaped humps with rises less than assumed 10 cm will result in higher speeds than those mentioned. Rises that are higher than 10 cm may cause damage to vehicles. For roads with bus traffic, the table indicates the speeds at which buses can reasonably pass the individual humps. If buses must be able to pass at 40 km/h, the radius of the hump must be 180m and chord length 12 m. **Fig. 3.1** gives the geometrical details of Road Hump.

Table 3.1 Recommended Radii and Chord Lengths, Circular Humps (Assumed Rise = 10 cm)

Desired Speed	Radius	Chord Length	Bus Speed During Passage
20 km/h	11 m	3.0 m	5 km/h
25 km/h	15 m	3.5 m	10 km/h
30 km/h	20 m	4.0 m	15 km/h
35 km/h	31 m	5.0 m	20 km/h
40 km/h	53 m	6.5 m	25 km/h
45 km/h	80 m	8.0 m	30 km/h
50 km/h	113 m	9.5 m	35 km/h

3.1.1.2 Trapezoidal Humps

A hump, which constitutes a 50 to 100 mm raised, flat section of a carriageway with ramps on both sides is called a trapezoidal hump. If designed correctly, the discomfort is moderate for cars, whereas lorries and buses must pass very slowly. **Fig. 3.2** gives geometric details of trapezoidal hump for various speed and also the speeds at which the buses may reasonably pass the individual humps. If buses must be able to pass at speeds of 35 and 40 km/h respectively, ramp lengths must be 3.3 and 4.0 m, and gradients 3.0 and 2.5 per cent respectively

Table 3.2 Recommended Ramp Lengths and Gradients, for Trapezoidal Humps)

Desired Speed	Length of Ramp	Gradient	Bus Speed During Passage
20 km/h	0.7 m	14.0%	-
25 km/h	0.8 m	12.5%	5 km/h
30 km/h	1.0 m	10.0%	10 km/h
35 km/h	1.3 m	7.5 %	15 km/h
40 km/h	1.7 m	6.0%	20 km/h
45 km/h	2.0 m	5.0%	25 km/h
50 km/h	2.5 m	4.0 %	30 km/h

THANK YOU