SaveLIFE FOUNDATION

Engineering Guidebook for Treatment of Critical Road Engineering Issues

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How to Use This Engineering Guide

This guide has been developed to support road owning agencies, constructing companies, and maintenance agencies in identifying and addressing critical road engineering issues that contribute to crashes and fatalities. It provides a structured, practical reference to help officials, engineers, and contractors design, maintain, and upgrade road infrastructure with safety at the core.

Purpose

India records some of the highest numbers of road crash deaths globally, and many of these are preventable through engineering solutions. This guide translates evidence-based practices, Indian Roads Congress (IRC) codes, and lessons from the Zero Fatality Corridor model into actionable steps for practitioners on the ground.

Structure

The guide is organised into thematic sections, each addressing a common type of crash or safety hazard—for example:

- Object Impact Crashes (collisions with roadside obstacles)
- Head-on and Run-off Crashes (due to median or shoulder issues)
- Rear-end, Sideswipe, and Fatigue-related Crashes
- Pedestrian Crashes and Work Zone Safety

Each section includes:

1. Scope – What type of crash or risk is being addressed.
2. Terminology – Key technical definitions.
3. Risk Factors – Typical causes and scenarios where crashes occur.
4. Recommended Treatments – Engineering measures and standards (referenced to IRC codes where applicable).
5. Case Examples – Where available, real-world results from implementation.

How to Apply

- **Diagnosis**: Use the guide during road safety audits, blackspot identification, and infrastructure planning to recognize hazardous features.
- **Design**: Apply recommended treatments when planning new roads, upgrading existing corridors, or redesigning junctions.
- **Maintenance**: Refer to the guide when repairing damaged infrastructure or reinstating markings, barriers, and signages.
- **Enforcement Support**: Combine engineering measures with enforcement and awareness strategies for maximum impact.

Key Principles

- Prioritise removal of hazards before relying on barriers.
- Ensure continuity and visibility in all safety features.
- Align all interventions with IRC standards and update them with routine audits.
- Focus on low-cost, high-impact solutions where possible.

Conclusion

This guide is intended to be a working document for engineers and decision-makers in highways and public works departments. Its consistent use will significantly reduce the risk of crashes, improve road user safety, and help India move closer to the goal of Zero Fatalities on its roads.

Section 1 - Object Impact Crash

1. SCOPE

This section of the code addresses the various factors for object impact crashes. The code highlights interventions that shall be adopted to reduce injury severity when a vehicle collides with a hard object within the clear zone. These hard objects may be removable or non-removable & present on the median shoulder, carriageway, or within the clear zone. Additionally, the objects may be large and easy to spot or small and difficult to spot by the driver. Some examples of such objects include and are not limited to concrete crash barriers, broken medians, large boulders, trees, bridge pillars, and parapet walls.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTOR

3.1 Object impact crash with non-removable large hard objects (>40 cm height) within the clear zone

It is to be noted that a clear, unobstructed, flat roadside is highly desirable. When these conditions cannot be met, barriers are needed. Object impact crashes with a large hard object over 40 cm height generally take place when a vehicle goes out of control. For instance, crashes with bridge parapet walls, large trees, bridge pillars, culvert walls, drainpipes, to list a few.

The removal of these hazards should be the first alternative to be considered. If it is not feasible or possible to remove or relocate a hazard, then a barrier may be necessary. However, the most appropriate barrier based on available space for deflection should be installed.

Type of Crash barrier

Crash barriers should be provided along the corridor where there is no sufficient run-away zone and the speed is greater than 40 km/h. The type of crash barrier depends on the speed, the predominant vehicle type, and the available deflection. The crash barrier should be provided such that the out-of-control vehicle hits the crash barrier first as it leaves the roadway.

Requirements of crash barrier

i. The space available behind the barrier must be adequate to permit the full deflection of the barrier.
ii. The barrier system must contain and redirect the vehicle at design conditions, not allowing it to penetrate or vault over the barrier.

iii. It must not cause sudden acceleration or spin of the vehicle.
iv. The vehicle must remain upright during and after the impact and there should not be any loose elements that can penetrate the vehicle.
v. After impact, the final stopping position of the errant vehicle must intrude only minimally into the adjacent traffic lanes.
vi. It must provide a good visual guide to the road users.
vii. It must not entail heavy maintenance expenditure.
viii. It must be possible to terminate the system properly
ix. It must involve reasonably low initial cost, maintenance cost and accident cost to the motorist.
x. It must have an aesthetically pleasing appearance.
xi. There must be documented evidence of the barrier's performance in the field.
xii. The barrier systems should be capable of redirecting the largest vehicle which is regularly present on the road.

3.2 Object impact crash with non-removable hard objects in the median

These crashes occur due to the presence of non-removable hard objects in the median. Generally, such crashes happen when an out-of-control vehicle runs into the median. Non-removable hard objects include but are not limited to boulders, gantries, trees, bridge abutments, super-structures, walls and large storm drains, are located within the median.

To minimize the impact due to such crashes, crash barriers should be provided along the median. The crash barriers shall be provided such that it prevents head-on collisions, especially on highways with narrow medians, caused by out-of-control vehicles jumping across the medians.

In the case of narrow medians, as generally provided in urban areas, New Jersey-type concrete crash barriers shall be used along with an anti-glare screen. Alternatively, a flexible crash barrier is preferable if there is sufficient space on the median for deflection of the crash barrier.

3.3 Object impact crash with a concrete crash barrier

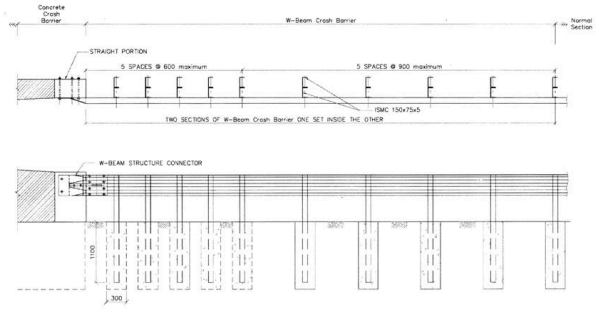
These crashes occur when a vehicle collides with the starting edge of the concrete crash barrier. Such crashes occur in the absence of proper crash attenuation, or due to damaged barriers or when there is an improper transition between a Metal Beam Crash Barrier and a Concrete Crash Barrier, or when there is a gap designed/ otherwise in the concrete crash barrier.

To minimize the impact due to such crashes, the following points should be considered:

i. Use of proper impact attenuators or crash cushions before the start of concrete crash barrier,
ii. Proper transition of crash barrier from flexible crash barrier to rigid concrete crash barrier. The approach and departure end of the rigid barrier shall be continued with a Metal beam barrier for a suitable length to ensure the continuity of the safety barrier,
iii. Timely repair or replacement of damaged crash barriers.

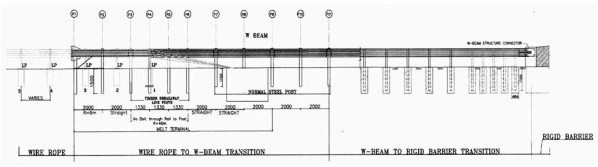
Transition of crash barrier from W Beam to Concrete

The W-beam to concrete transition shall be carried out by decreasing the post spacing, nesting one rail behind another and using a steel section behind the W-beam. The transition between W-beam and concrete barrier is detailed in figure below.



Transition of crash barrier from Wire Rope to Concrete

The figure below shows the transition from wire rope to concrete.



3.4 Object impact crash with difficult to spot hard objects

It has been observed that many times crashes occur due to difficulty in spotting hard objects. For instance, due to low light conditions on the road hard objects may not be visible due to which a vehicle may collide with such objects.

In order to minimise the impact of such crashes such spots should highlight objects with poor conspicuity using hazard marking or object markers. Safety requirements mentioned in IRC 79:2019 & IRC 35:2015 shall be followed.

3.5 Object impact crash with small hard objects

Crashes may also occur due to a vehicle colliding with a small hard object like kerbs, milestones markers, construction material, etc.

In order to minimise impact crashes with small hard objects, such small hard objects should be removed from clear zone and median or should be well delineated using retro-reflective paint marking or tapes or indicators. Safety requirements mentioned in IRC 119:2015 & IRC 79:2019 shall be followed.

3.6 Object impact crash with broken median infrastructure

Structures like median curbs are supposed to be designed to yield to impact force and, thereby, control the counterforce sustained by the vehicle striking the breakaway support[1].

Thus, when such structures are broken, and not repaired in time, the chances of injury during a subsequent crash increase. In order to prevent such a form of injury, all broken and discontinuous median curbs should be treated within 48 hours. The maintenance work shall include:

i. Closure of all unauthorized/broken median openings is needed at a regular interval
ii. Repair of crash barriers post-crash
iii. Road owning agencies shall ensure regular audits to identify and rectify newly created issues. A summary audit of the state of the highway shall be carried out on a monthly basis.

In addition to the summary audit, the road owning agency shall ensure that the road infrastructure is repaired after every known crash.

Case Example:

On NH 48, under the Zero Fatality Corridor initiative, 17 gaps in median were treated. As a result of the treatment, there has been a marked reduction in crashes at the treated intersections.

[1] Wang, Y. G., Chen, K. M., Ci, Y. S., & Hu, L. W. (2011). Safety performance audit for roadside and median barriers using freeway crash records: case study in Jiangxi, China. Scientia Iranica, 18(6), 1222-1230.

3.7 Object impact crash with objects on road

It has been observed that many times crashes occur with hard objects on the road. While no objects are allowed on the travel way, crashes occur with some objects left behind post maintenance, post-crash, or post construction activity. The solution to this issue is the immediate removal of all objects on the road

Section 2 – Head-on Crash

1. SCOPE

This section of the code gives recommendations for reducing head-on crashes. It highlights interventions that shall be adopted to prevent the collision of two or more vehicles that are moving in opposite directions on adjacent lanes of the main carriageway of the highway, where there is no demarcation or division of road based on an upward and downward journey for vehicles.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Head-on crash with vehicles of the opposite corridor

Head-on crashes generally take place on highways or roads where physical median barriers are absent or where the median barrier is ineffective or damaged. A vehicle traveling at highway speeds can cross over a highway median and strike opposing traffic head-on, causing serious injuries.

Median crossover crashes typically result in frontal or side impact crashes. Generally, in such crashes the damages are extremely high due to the high speed at which the vehicles collide. Often such crashes lead to the vehicle's passenger compartment being crushed, thereby injuring the passengers.

In order to prevent this form of road crashes, suitable crash barriers should be placed at the median. The broad specification and requirement of crash barrier is discussed in section 1 of this chapter.

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Section 3 - Run-off crash

1. SCOPE

This section of the code specifies ways to prevent run-off on highways. There are a number of reasons due to which run-off may occur, the most common reasons for crashes due to run-off are - steep non-recoverable slopes, gaps in crash barriers, insufficient warning at curves, fatigue, and inadequate visibility.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

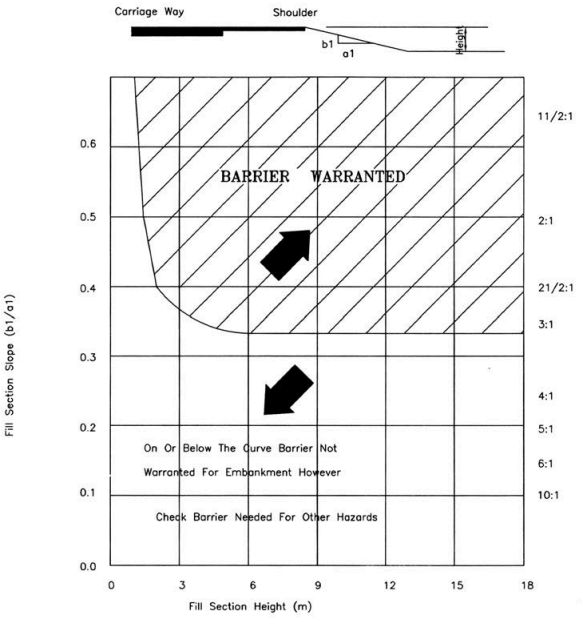
3. TYPES OF RISK FACTOR

3.1 Run-off crash along steep non-recoverable slopes

Steep slopes are non-drivable and non-recoverable slopes. Such slopes increase the risk of an errant vehicle to overturn. Overturning/roll-over crashes often result in serious injuries or fatalities. In order to prevent such run-off crashes, it is important that crash barriers be constructed along steep slopes.

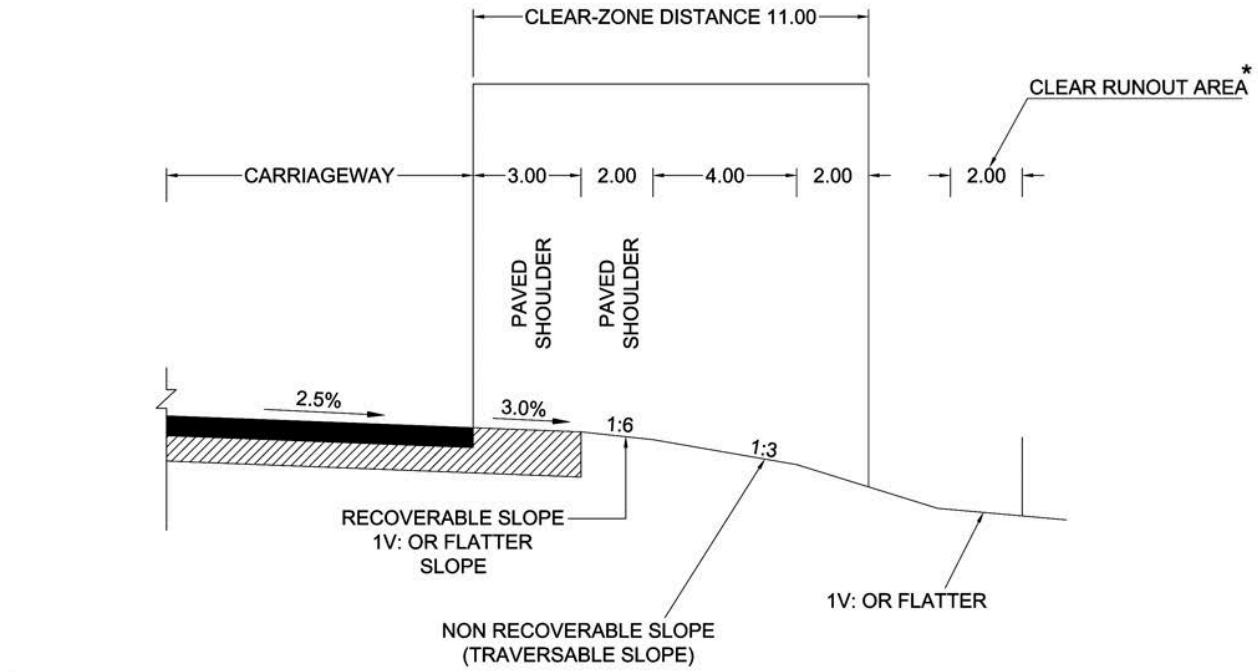
The warrants for the installation of road edge barriers on road embankments are governed by the height and slope of the embankment. These are given in figure below.

It may be noted that the barrier is not warranted for embankment slope of 3:1 or flatter.



For high-speed corridors, it is necessary to provide roadside safety barriers on embankments where the recoverable slope upto a distance of clear zone applicable for the design speed is not available as shown in image below.

The broad specification and requirement of the crash barrier is discussed in section 1 of this Part.



*THE CLEAR RUNOUT AREA IS ADDITIONAL CLEAR-ZONE SPACE THAT IS NEEDED BECAUSE A PORTION OF THE SUGGESTED CLEAR-ZONE (SHADED AREA) FALLS ON A NON-RECOVERABLE SLOPE

3.2 Run-off crash due to gaps in crash barrier

Occasionally, gaps in guardrails are provided to accommodate trees, pillar boxes, signposts, electrical control boxes, etc. These often turn out to be dangerous especially from the perspective of road crashes.

Case Example:

A 178 km metal beam crash barrier was installed on the Mumbai Pune Expressway which led to a 52% fatality reduction on the Zero Fatality Corridor Project in the year between 2018 and 2020.

Thus, in order to prevent such crashes:

i. Unnecessary gaps in the crash barrier should be closed. The median crash barriers should be smooth and continuous.
ii. Routine maintenance of the crash barriers should be conducted to ensure that no broken/ damaged crash barrier system is present on/ near the roadway.

3.3 Run-off crashes at curves due to insufficient warning

Insufficient warnings on the curves lead to high risk while driving on the roads, as the driver is unable to see what lies ahead especially if there is a narrow lane ahead, change in road alignment etc.

Installing chevron signs at sharp curvature shall provide drivers an idea about the sharp curve ahead.

Safety requirements to be followed as per IRC 67-2012, Section 4.1,4.2,4.3,4.4, Siting of signs with respect to the carriageway (Page 6), Section 14, Mandatory/ Regulatory signs (Page No.24)

Section 15, Cautionary/ Warning Signs (Page No.36), Section 16, Informatory Signs (Page No.46), Section 5.1, Orientation of Signs (Page 8)

3.4 Run-off crashes due to fatigue

Driver fatigue (tiredness, drowsiness) has been one of the main causes of countless crashes. In order to prevent rear-end crashes due to fatigue, a consistent application like Audio Tactile Line Marking (ATLM) should be designed to address the risk of head-on crashes and run-off road crashes. Reference to the same can be found in subsection 3.21 of part IV of this Part.

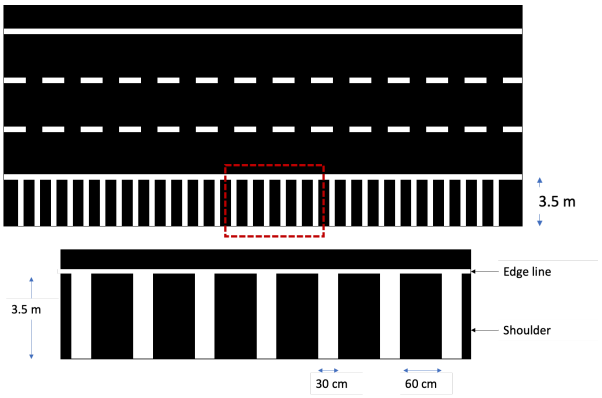
Based on a study of the Zero Fatality Corridor it has been observed that after the installation of Audio Tactile Line Marking (ATLM).[2] There is a significant reduction of run-off crashes due to Fatigue.

ATLM involves installing a series of raised extruded thermoplastic bars that give an audible sound and vibration when traversed by a vehicle. This low-cost treatment follows Safe System principles and should be considered as one of a number of available options in achieving Towards Zero deaths and serious injuries. ATLM is considered to be a supporting treatment towards Safe System as it provides some crash reduction without providing a physical separation by a space or barrier between opposing traffic lanes. It is suggested that ATLM reduces not only the likelihood of head-on and run-off road crashes but also the severity as it may provide

[2]https://www.vicroads.vic.gov.au/-/media/files/technical-documents-new/road-design-notes/road-design-note-0310-audio-tactile-line-marking-atlm-v10-june-2020.ashx

some drivers opportunity to apply emergency braking or steering to reduce the impact.

An illustration of the Tactile Shoulder Line with respect to the expressway is shown below. The area highlighted in the Red dotted line is illustrated in-depth in the subsequent figure



3.5 Run-off crash due to low-visibility crashes with the edge of the road

Roads with poor visibility are dangerous especially at night, as it could lead to the risk of fatal or serious injuries in a road crash.

Delineating highways with retro-reflective material shall be a major step to prevent such crashes.

Section 4 - Impalement

1. SCOPE

Impalement may occur when there is an untreated end of the steel type road edge/ or median barrier on/ near the main carriageway of the highway or road. It can be hazardous if hit because the barrier beam can penetrate the passenger compartment and cause the impact vehicle to stop abruptly. End treatment should, therefore, form an integral part of safety barriers. An end treatment should not spear, vault, or roll a vehicle for head-on or angled impacts.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

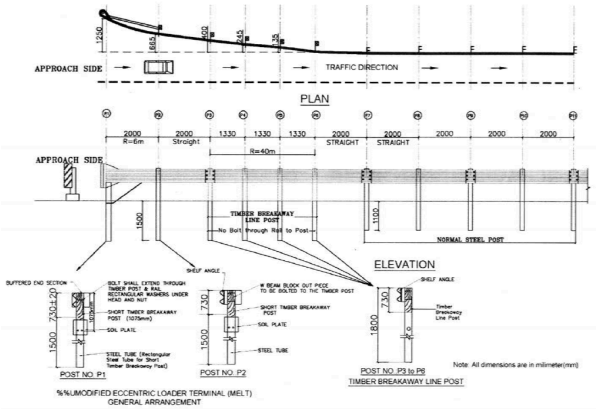
3. TYPES OF RISK FACTORS

3.1 Impalement of the steel type crash barrier to the vehicle

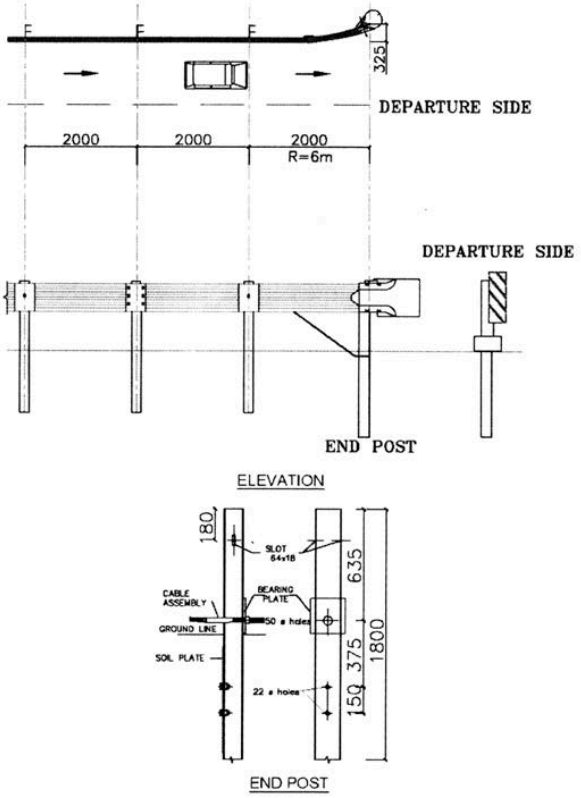
Sometimes a vehicle loses control due to over speeding, and the front of the vehicle impacts the end of the steel type crash barrier. If the end treatment of the steel-type crash barrier is not done, the crash barrier will impale into the vehicle and cause a serious crash injury.

An untreated end of the roadside barrier can be hazardous if hit, because the barrier beam can penetrate the passenger compartment and cause the impact vehicle to stop abruptly. End treatments should, therefore, form an integral part of safety barriers. An end treatment should not spear, vault or roll a vehicle for head-on or angled impacts.

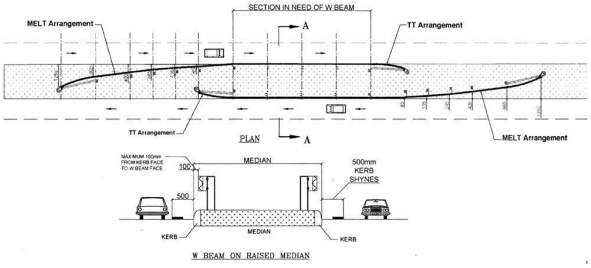
The end treatment on approach shall be Modified Eccentric Loader Terminal (MELT) arrangement as shown in figure below.



In the departure sides, it shall be the Trailing Terminal (TT) arrangement shown in figure below.



Following the same end treatments, figure below gives the typical layout of W-beam whether on raised median sides or on depressed/flushed median sides.



At road cross-sections in cutting or if the road transitions from cut to fill, the safety barriers can be anchored in back slopes. The backslope covering the anchored portion of the barriers should be graded flat, with side slopes preferably not steeper than 10:1. The anchored portion should develop tensile strength in the rail element to prevent the rail from pulling out of the anchorage. The barrier can also be anchored in an earthen berm specially constructed for this purpose, provided the new berm itself is not a hazard to the traffic. The earthen berm should be made resistant to erosion.

Care must be taken that the end treatment on approach is Modified Eccentric Loader Terminal (MELT) arrangement and departure sides are of Trailing Terminal (TT) arrangement.

The **Modified Eccentric Loader Terminal (MELT)**[3] is designed to provide a soft, gating impact and reduce the severity of impacts occurring at the end of the safety barrier system. The MELT is a **parabolic-fared** terminal with W-beam rails supported by specially engineered, steel breakaway posts. The parabolic flare positions the end of the safety barrier system away from oncoming traffic. The MELT also anchors the safety barrier system and is suitable for use on the leading and trailing end of a safety barrier system

[3]https://www.abovebeyondconcepts.com.au/index.cfm?module=storetigerv2&bit=products&product_id=249545&product_tab=description

Section 5 – Wrong or Unpredictable Movement of Motorists

1. SCOPE

There can be various reasons why a motorist makes a wrong decision on the road and makes a wrong move. Some of the major reasons for such wrong/ unpredictable movements of motorists include lack of communication or wrong communication to the motorist, in order to avoid any hazard such as potholes, shoulder edge drop, lack of / faded road marking, inefficient road network planning, and lack of awareness of the road users.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPE OF RISK FACTORS

3.1 Wrong/Unpredictable movement of motorists due to lack of communication

The road signs are the means of communication to the road users, especially motorists. When such signages are absent the motorist/ driver may not be aware of what lies ahead on the road and thus may make the move based on his/ her prediction which may lead to a crash.

In order to avoid such crashes, it is important to install appropriate signages at relevant points on roads. The specification of road signages should follow IRC 67:2012 guidelines.

3.2 Wrong/Unpredictable movement of motorists due to wrong communication

There is an extreme chance of road crashes when the signages placed on the road are misleading or wrong. For instance, if signage indicates that there is a ‘curve ahead’ whereas the actual road has a ‘slope ahead’, the motorist may be misguided and may not be able to take the necessary precautions to drive on a slope, thereby increasing the chance of a road crash.

In order to prevent such crashes due to misinformation, it is essential to remove wrong signages from the roads. The specification of road signages mentioned in IRC 67:2012 should be followed.

3.3 Wrong/Unpredictable movement of motorists due to non-visible communication

Obstructed view of signages, whether caused by vegetation (e.g., bushes, trees), other signs or street furniture (e.g., crash barriers), may not allow a motorist to view the signage on the road which may lead to wrong or unpredictable movements of the motorist that

can consequently lead to road accidents. In order to prevent such road accidents, it is essential that drivers and other road users should have a clear view of road signs. Thus, it is essential that obstruction caused by vegetations should be regularly trimmed and maintained. The signage installation guidelines mentioned in IRC 67:2012 should be followed.

3.4 Wrong/Unpredictable movement of motorists (to avoid potholes)

Non-maintained surface roads can be expensive not only from the perspective of the number of lives lost due to such surface defects but also increases - vehicle operational cost, rise in the cost of restoration/ reconstruction of roads, etc.

Thus, in order to prevent such forms of accidents, it is essential to treat the surface defects and conduct routine maintenance of the same. Safety requirements to be followed as per IRC 082:2015, "Sections 3 & 4"

3.5 Wrong/Unpredictable movement of motorists (lack road markings)

One of the common causes of road accidents is the lack of road and pavement markings. Proper signs and road and pavement markings ensure and guide motorists/drivers and pedestrians to the right direction and periphery of the movement. Such markings act as a safety signal to any individual stepping out on the road.

Case Example:

On the Mumbai Pune Expressway 400 road signages were installed across a stretch of 94.5km which lead to a 52% fatality reduction on the Zero Fatality Corridor Project in the year between 2018 and 2020

3.6 Wrong/Unpredictable movement of motorists (faded road markings)

As discussed in the previous section, road markings are extremely important.

Faded road markings shall be non-effective as they shall not be clearly visible to pedestrians or motorists on the road.

Thus, to avoid wrong or unpredictable movement of motorists, reinstating faded pavement marking should be done on a regular basis. The same can be partially found in New Zealand's Road Maintenance Program.

3.7 Launching of vehicles into air due to sloped crash barrier end treatment

When a vehicle crashes with sloped crash barriers, it launches the vehicle into the air and the driver loses all control of the vehicle. To prevent such situations, the crash barrier ends shall be treated as mentioned in Section 4, 3.1

Sloped crash barriers shall be treated to ensure that the slope is eliminated or protected similar to a large hard object.

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Section 6 – Rear-End Crash

1. SCOPE

A rear-end crash occurs when a vehicle crashes into the one in front of it. Common factors contributing to rear-end crashes include driver inattention or distraction, speed inconsistency, the presence of parked vehicles, and poor pavement conditions. This section of the code discusses the various factors that lead to rear-end crashes and the preventive measures that should be adopted.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Rear-end crash due to parked/stopped vehicles on the shoulder

Several times, it has been seen that vehicles are parked on the shoulder. The presence of parked vehicles on the shoulder could be a significant cause of rear-end crashes, especially at night-time. Reference to the same can be found in subsection 3.1 of Part IV of this Part.

Vehicles generally stop on high-speed corridors only when it is an emergency or due to break down. In such cases, adequate visibility is the only viable solution to ensure safety. To ensure that adequate visibility is available, vegetation shall be trimmed along curves. Speed of the corridor shall be limited to the visibility available rather than the design speed of the pavement.

3.2 Rear-end crashes due to haphazard stopping of trucks on the side of the highway

Crashes often occur due to haphazard parking of trucks on the side of the highway. Truckers are forced to park haphazardly as, often, there is no designated parking area for parking.

Further, it has been seen that vehicles carrying iron rods, or other objects, that protrude from the body of the vehicle often pose a serious risk of accidents like

impalement resulting in the loss of life and property of others commuting on the same road. For instance, when a truck carrying iron rods suddenly breaks, the vehicle behind is caught unawares, almost always resulting in a fatal accident for those travelling in the vehicle behind. This problem gets aggravated further when such a truck is left irresponsibly stalled on the road. Thus, it is recommended that no vehicle running on the highway shall carry any protruding rod.

It is also recommended that in order to avoid crashes due to haphazard stopping of trucks on the side of the highway, by-lanes should be constructed for trucks. Such by-lanes should be constructed in the following manner:

i. Maintain adequate number and size of truck lay-bye for parking of trucks by the side of the project highway
ii. Truck lay-byes shall, in general, be located near check barriers, interstate borders, places of conventional stops of the truck operators, etc. The places will be identified on the basis of field survey and shall have adequate space for facilities as specified in this section and future growth.
iii. The truck lay-byes shall have the following facilities - Paved parking, Rest areas with toilets, shower, drinking water, and a restaurant.
iv. The truck lay-byes and 50 m length of the project highway on either side shall be illuminated at night to provide an average illumination of 40 Lux. Suitably designed electric poles having aesthetic appeal and energy-saving bulbs may be used to provide the required illumination. Alternatively, illumination solutions may also be used as it is not hazardous to the drivers, and provides the recommended intensity of illumination.

3.3 Rear-ending crash due to lack of emergency stopping space

Rear-ending collisions may take place due to emergency stopping of a vehicle on the road. In order to prevent such crashes, it is quintessential to provide emergency stopping space on the highways.

These emergency stopping spaces can be road shoulders, which are strips of land immediately adjacent to the traffic lane of a road not bordered by kerb and channel. Shoulders are provided along the road edge to serve as an emergency lane for vehicles compelled to be taken out of the carriageway or roadway. Shoulders also act as service lanes for vehicles that have been broken down.

As per IRC SP 87: 2019, shoulders along the highway should be of a minimum of 2.5 meters wide (paved) and 1.5-meter (unpaved).

In addition to emergency stopping space, there needs to be safety treatment at steep slopes as per IRC:SP:48-1998.

3.4 Rear-ending Crash due to speed inconsistency between Vehicles

Rear-ending crashes due to speed inconsistency between vehicles is extremely common. The possibility of rear-ending crashes increases if the speed difference between two successive vehicles is significantly high.

One of the main reasons that rear-end collisions occur is because not enough space is left between drivers for the rear driver to stop in time without hitting the back of the first driver's vehicle. For this reason, it is advised to maintain a safe following distance. Reference to the same can be found in subsection 3.20 of Part IV of this Part.

The recommendation is to abide by the three-second rule for determining whether or not you are safely far enough behind the first driver. The three-second rule simply requires that you look at a stationary object next to the driver in front of you and if you can count to three before you pass the same object, you are too close.

Section 7 – Construction Zone/Work Zone Crash

1. SCOPE

The road construction zones/work zones are areas of conflict between normal operating traffic, construction workers, road building equipment, and construction traffic. If it is a construction of a new road, normal operation of traffic will be disrupted. However, care needs to be taken to avoid and or remove conflicts between workers and construction machinery and traffic. The problem becomes more severe with the presence of vulnerable road users.

Construction Zone/Work Zone crashes are caused by several factors such as frequently changing environments that occur during road work whereby the driver is often surprised, insufficient warning signs for normal and construction traffic, lack of audible warning to workers, and inadequate provisions of safety devices to protect workers. At most construction zones/work zones, normal traffic is never more than 15 meters away from construction activities.

Major contributing factors to Construction Zone/Work Zone accidents include poor attention to the dangers, travelling too fast for the prevailing conditions, failure to yield the right-of-way, following too close, and lack of awareness of the construction/work zone.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Crash due to Construction Zone/Work Zones which creates a sudden change in the general road environment and sudden lane drop

Crashes on the road may occur due to the Construction Zone/Work Zone as the operating condition of the road changes because of construction and maintenance activities of the road, the drivers may not be aware of the change in the road condition. If such roads remain untreated the chances of road crashes increase. Thus, Construction Zone/Work Zones should have advanced warnings suggesting - the length of temporary traffic, presence of hazard marker sign, change in traffic arrangement, transition zone where the drivers are redirected from the normal path of travel, etc.

Further, flagmen should be deployed for safety compliance according to Section 9, of IRC SP 55-2014 in the following manner:

i. The flagmen or flaggers shall be deployed where -
   a. Workers or equipment intermittently block an unprotected traffic lane

b. One lane is used for two directions of traffic
c. Guidance, warning, and control of traffic is considered necessary

ii. The flagman shall be physically fit, well trained, alert, and capable enough to effectively perform the assigned duties.

iii. Flagman shall be provided with hand signalling devices such as flags and sign paddles.

iv. Flagmen must be provided with and must wear warning garments, safety headgear, footwear and gloves for their protection and for conspicuity, while flagging. Warning garments worn at night must be of reflective material.

v. Flags for signalling shall be minimum of 600 mm x 600 mm in size made of good red cloth and securely fastened to a staff of approximately 1m length. Sign paddle should be atleast 600 mm wide provided with a rigid handle. The background colour of STOP should be red and its shape shall be octagonal. The word STOP would be in white colour. Similarly, the background of SLOW sign should be yellow with black letters, and the GO sign shall be with green background with white letters.

vi. The control of traffic through the work area is an essential part of road construction and maintenance operations.

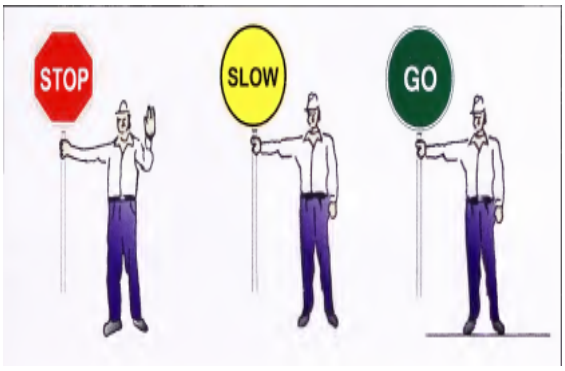
vii. Flagmen with hand signalling devices such as sign paddles play a crucial role in this context. STOP, SLOW, and GO paddles are used, and in some cases, temporary traffic lights are used in controlling traffic through the work area.

Besides red and green flags, octagonal and round-shaped hand paddles of 600 mm x 600 mm should be used with red, yellow, and green retro reflective if used at night time, whereas red and green flags can be of visible fabric materials for daytime usage.

Since Flagmen are responsible for the safety of road users and the workers, it is important that qualified personnel be selected. The flagmen at the worksites are expected to stop traffic intermittently and to maintain continuous traffic flow at the work site at reduced speeds to help protect the workmen. For both of these functions, the flagmen must, at all times be clearly visible to approaching traffic for a distance sufficient to permit a proper response by the drivers to the flagging instruction and to permit traffic to reduce speed before entering the worksite. This distance is basically related to approach speed and site conditions; however, 60 m to 100 m is desirable. In urban areas, this distance shall be reduced from 20 m to 50 m.

Another modern method is Marshalling torches are:

i. Hand flashers are tough and durable working on normal or rechargeable batteries with LED bulbs.
ii. To provide warning signal for impending hazard or danger on construction Construction Zone/Work Zone, repair sites, trenches, digging of road tunnels



Drivers should slow to the posted speed limit and move to the proper lane as instructed.

To avoid crashes, use safety cones, barrels, and barriers to clearly delineate specific areas of the Construction Zone/Work Zone such as material storage, areas where heavy equipment is being used, vehicle parking, and safe areas for workers on foot to move around. The traffic management practices at worksites mentioned in Section 7, of IRC SP 55: 2014 should be followed.

Section 8 – Loss of Vehicular Control

1. SCOPE

One of the very common causes of road crashes is loss of vehicular control which results in skidding. Loss of vehicle control is a common problem that frequently leads to major crashes that result in severe injuries for all those involved.

Common reasons why a driver may lose control of their vehicle and skid include

i. Skidding due to smooth surface
ii. Skidding due to difference in level
iii. Speeding, which generally makes it harder to control a vehicle, particularly around curves
iv. Vehicle Out of Control due to Mechanical failures.
v. Skidding due to poor drainage of water

Driving under the influence is also a common factor in these car accidents. Driving impaired makes you less likely to respond appropriately when loss of control does occur. A vehicle can skid on the road due to the road surface being slippery, a vehicle may also skid due to the unevenness of the road.

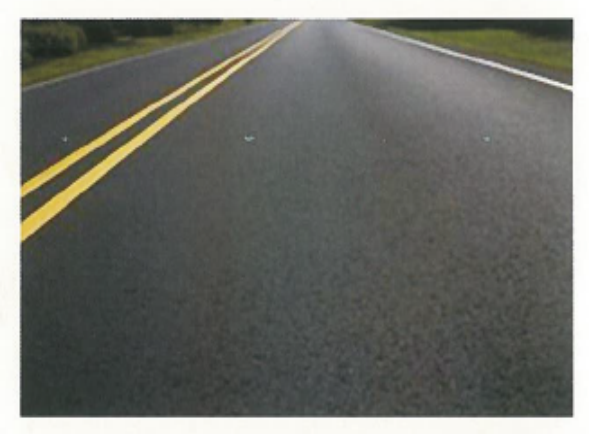
2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Skidding related crash due to smooth surface

Crashes may occur due to slipping on a smooth surface, as such surfaces are low skid resistant and become very slippery when it is wet (IRC 82-2015, Section 7.2.2.). Such a condition invites safety hazards, especially on gradients, bends, and intersections. A primary cause for a smooth surface is the polishing of aggregates under traffic. Excessive binder can also contribute to the formation of a smooth surface.



In order to prevent such crashes, **c**are should be taken to select aggregates that have proven non-polishing characteristics. Slurry seals can

also be used to impart anti-skid texture on a smooth surface.

3.2 Skidding due to difference in level (during overlay of the road)

Skidding related crashes may also take place when there is a difference in the level of a road. The presence of a significant level difference between the major and minor carriageway at a junction increases the probability of vehicular skidding while maneuvering from minor carriageway to major carriageway or vice versa. In order to avoid such crashes, the treatment of the road surface should be performed. There should not be any level difference between major and minor carriageways.

3.3 Vehicle Out of Control due to Over speeding

In general, excess speeding increases the possibility of vehicles being out of control. Speeding drivers may lose control of their vehicles more easily. Reference to the same can be found in subsection 3.3 of part IV of this Part.

Hereby, it is recommended that

i. Speed signs are installed at regular intervals to inform traffic on the safe speed of the highway
ii. Traffic calming measures be provided at accident-prone zones/ or black spots to avoid chances of overspeeding crashes. The basic principle of traffic calming measures is to lower vehicle speeds in order to reduce accidents.

3.4 Vehicle Out of Control due to Mechanical Failure

Mechanical failures, such as tire blowouts and brake failures, lead to loss of control on the vehicle consequently leading to crashes. In order to prevent such crashes routinely, check on vehicles should be conducted.

3.5 Skidding due to poor drainage of water

Chances of road crash increase when there is the pooling of water due to poor drainage. There should not be standing water on the road. The specification is mentioned in Section 15.

Section 9 – Crash Due to Loss of Vehicular Control

1. SCOPE

This section of the code discusses the various risk factors due to which vehicles lose control and crash. The section scopes out the measures that should be adopted to prevent such crashes.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Crash due to Surface Defects

There are numerous types of defects that form on roads including deep potholes, shallow potholes, surface deterioration, edge failure, cracking, rutting, and subsidence, which can lead to fatal or serious injuries. In order to prevent crashes due to surface defects standards mentioned in IRC 82:2015 should be followed i.e. The shoulder and the pavement materials in the affected area should be fully removed to a regular section with vertical sides. The pavement and the shoulders should be built up simultaneously with thorough compaction. A bituminous surface similar to that in the adjacent reach should be laid. The shoulder should have adequate slope to drain away to water. A slope one percent steeper than the camber of the bituminous surface should be found generally necessary for earthen shoulders. In order to prevent the edges from getting broken again, the maintenance operations should include periodic inspection of the shoulder condition and replacement of worn-out shoulder material with adequate compaction. In sandy areas where the soil is likely to be eroded by wind and rain, it may be advantageous to have brick paving at least for some width to protect the edges. Surface and subsurface drainage, wherever deficient, should be improved.

3.2 Crash due to loss of control (Unmarked Speed Humps on Road)

Speed humps are parabolic vertical traffic calming devices intended to slow traffic speeds on low volume, low-speed roads. Speed hump should be marked with thermoplastic paint or retro-reflective paints. The absence of marking on the speed humps shall be identified as unmarked speed humps. The absence of marking on the speed hump may lead to sudden braking by the speeding vehicle and may result in a loss of control type crash, especially at night. IRC 099:2018 shall be followed.

In order to prevent such crashes speed humps should be clearly marked with retro-reflective paints to give the driver the time needed to slow down the vehicle well in advance. Further, speed humps should be highlighted along with a warning sign of "Speed hump ahead" placed before the hump. The distance of the sign to be placed should be at least 50-100m before the hump for lower-speed highways.

3.3 Crash due to loss of control (Unauthorized Humps on Road)

Road crashes may occur due to surface defects like uneven and bumpy roads especially if the roads are not well planned and maintained. It becomes extremely difficult for a driver to be cautious about the surface defects ahead which may lead to road crashes.

In order to avoid such crashes, it is essential that speed breakers markings be supplemented with warning signs in advance of zebra crossing location and informatory signs at the location of the zebra crossing. Roads should have markings to warn drivers about hazards ahead in advance. For better night-time visibility, the marking shall be made retroreflective and reinforced with road studs.

Care should be taken that such markings are made with Solar Powered Road Markers, as they are more effective and can immediately draw the attention of drivers. Such markings shall be provided at locations like approach to speed humps. Safety requirements to be followed as per IRC 035:2015, Section 11.1 Marking on speed breakers (Page No. 71)

3.4 Crash due to loss of control (sudden level difference at edge of the road)

Crashes may occur when a driver loses control of his/ her vehicle due to unevenness of the road, or edge drops at the soft shoulders.

In order to prevent such crashes:

Periodic Maintenance of Soft Shoulders [4]

Soft shoulders such as earthen or granular shoulders should be periodically maintained by levelling and compacting to avoid drop-off (depression at road edge), erosion, and consequential channelized flow of water in

[4] IRC SP 42:2014, Section 4.4.5, Drainage of Shoulders (Page No.18)

the longitudinal direction. Care should be taken to add fresh material to compensate for the loss of soil due to erosion, vehicle movement, etc., and compacting the same after mixing necessary moisture to achieve Maximum Dry Density (MDD).

Section 10 – Crash Due to Sudden Appearance of Vehicle

1. SCOPE

This section of the code gives recommendations for reducing crashes due to the sudden appearance of vehicles due to lack of certain planned & preventive measures.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Crash due to sudden appearance of vehicles (U-Turn/ Right-turning vehicles from the median)

Road crashes may occur when there is a sudden appearance of vehicles especially at the turning points, and medians. The gaps in the crash barrier are frequently utilized by motorcyclists to a crossroad, resulting in an unsafe crossing of the road.

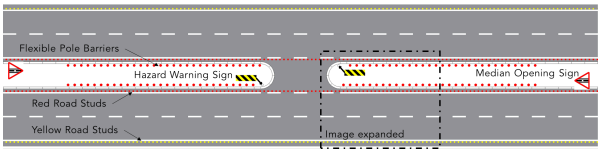
In order the prevent such crashes, treatment of the median gap should be done to improve conspicuity. The following standards mentioned in IRC SP 88-2019 should be followed.

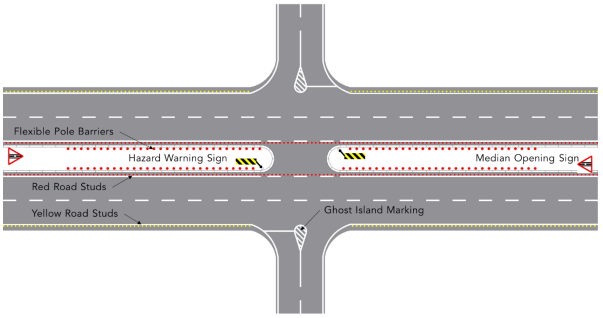
i. The unnecessary gaps in the crash barrier should be closed. The median crash barriers should be continuous.

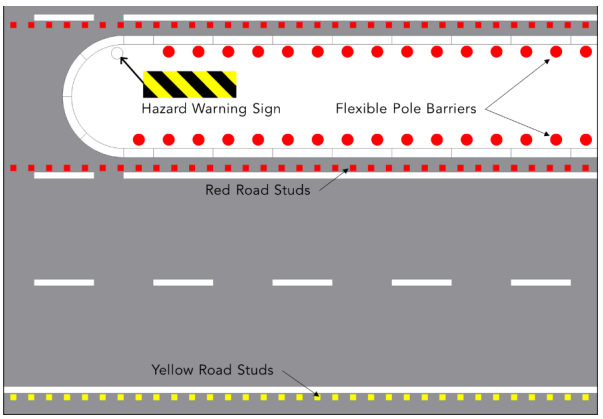
ii. Regular asset management checks should be conducted to ensure that there is no broken crash barrier.

iii. Care must be taken that every unauthorized gap in the median is closed.

iv. Authorised gaps in the median shall be treated to improve visibility and safety.







Case Example:

As a part of the zero fatality corridor initiative on Mumbai Pune Expressway (MPEW), all unauthorized medians were closed. The number of gaps in the median was limited to required openings for emergency vehicles. The closure of median openings led to a significant reduction in fatalities on MPEW

3.2 Crash due to the sudden joining of vehicles from the service road to the highway

Road crashes may occur due to the absence of properly designed entry/exit ramps connecting the access between the service road and highway as there may be a sudden joining of vehicles from the service road to the highway.

In order to avoid such road crashes, standards as mentioned in IRC SP 87: 2019 shall be followed i.e. the service roads shall be connected to the main highway through properly designed entry/exit ramps at locations.

Traffic needing access to the main highway shall first come onto the service road and then join the main highway through an acceleration lane/entry ramp.

Similarly, all traffic exiting the main highway shall first come on to the service road through a deceleration lane/exit ramp from where it would distribute to the local road network for various destinations.

However, when there is no settlement or roadside development abutting the Project Highway or the connecting roads are spaced more than 2 km, service roads may not be necessary and access can be given directly through acceleration/deceleration lanes.

The existing direct access to the highway shall also be modified accordingly

3.3 Crash due to sudden appearance of vehicles on the highway from minor roads

Road crashes may occur when a vehicle enters a highway through a minor road, as the drivers driving on the highway may not be aware of such minor intersections from where vehicles may appear on the highway. In order to avoid such road crashes minor intersections should be regularly treated and maintained.

3.4 Crashes at intersection

Crashes at intersections are common on highways. It is recommended that there shall be no intersections on highways. In the rare instances where intersections needs to be provided, the following measures shall be undertaken:

i. It is recommended that, the intersection shall be converted to a vehicle underpass or vehicle overpass.
ii. The intersection may be redesigned to form a series of safe minor road junctions and median openings.
iii. If traffic volume is high, the intersection may be converted to a signalised intersection
iv. There shall be illumination to ensure adequate visibility.

In many cases, crashes at intersections occur with pedestrians. Such crashes are described in Section 12 - Pedestrian Crash.

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Section 11 – Crash Due to Poor Driving Behaviour

1. SCOPE

This section of the code gives a clear idea of the crashes that often occur due to poor driving behaviour like overtaking using the shoulder. Not all poor driving behaviour can be treated through engineering measures, however, the road infrastructure should ensure that there is clarity in how the driver is expected to perform.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Crashes due to Overtaking using the shoulder

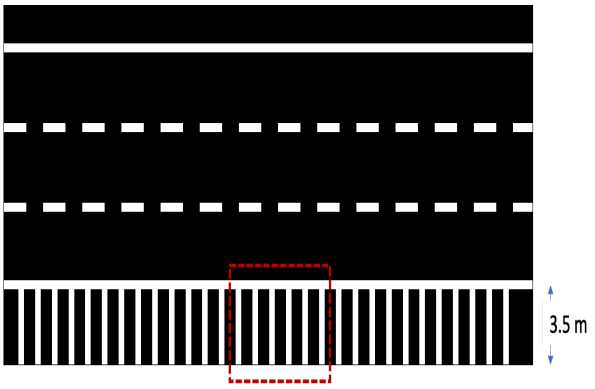
Road crashes may occur due to vehicle overtaking. Overtaking often takes place through the shoulder.

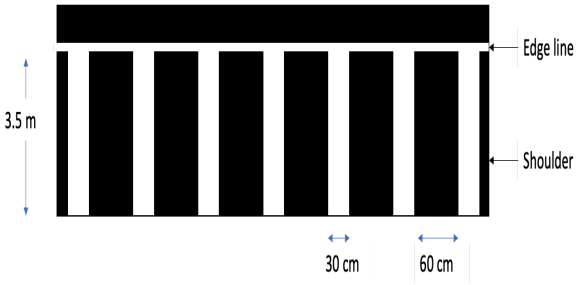
In order to prevent such crashes, Tactile Shoulder Line (TSL) should be installed. TSL will actively assist in preventing overtaking behavior using shoulder and rear-ending crashes. Reference to the same can be found in subsection 3.6 of Part IV of this Part.

In order to prevent crashes due to overtaking from the shoulder, Tactile Shoulder Lines should be constructed by every national and state highway. The measurements are mentioned in the illustration below. The thickness of the edge line shall be 10mm.

Case Example:

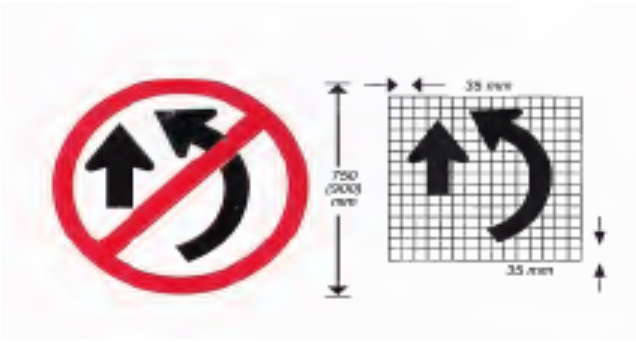
In Mumbai Pune Expressway after installation of Tactile Shoulder Lines, overall road crashes significantly reduced.





Warning signages mentioning (Overtaking Prohibited) should be placed at locations that are accident-prone zones/ black spots encountering road crashes due to overtaking. The “No Overtaking” sign should be erected on each side of the road at the start of the affected length and should be supplemented by repeater signs at intervals not exceeding 400 m.

Safety Standard as per IRC 67-2012, Section 14.7.20; IRC 35-2015



3.2 Crashes due to over speeding

The details of over speeding are discussed in Section 8 (3.2). Reference to the same can be found in subsection 3.3 of Part IV of this Part.

Section 12 – Pedestrian Crash

1. SCOPE

This section of the code discusses some of the most common risk factors of pedestrian crashes and how such crashes can be prevented.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Pedestrian crashes due to pedestrians on the main carriageway

Road crashes often occur when pedestrians indiscriminately use the main carriageway.

In order to prevent such crashes, the provision of safe and continuous pedestrian infrastructure should be built following the standards laid in IRC 103:2012 & IRC SP 84:2019.

3.2 Pedestrians crash during the wait on the shoulder for public transport

The absence of a designated bus stop or the presence of a dysfunctional bus stop is a significant problem on Indian highways. In the absence of designated bus-stop facilities, buses stop anywhere, compelling pedestrians to wait on the main carriageway or shoulder; as a result, the risk of pedestrian-vehicular crashes increases. Further, the lack of proper access to the bus stops from the pedestrian sidewalk and crossing facilities, forcing pedestrians to take the unnecessary risk of dangerous crossing. Additionally, a stopped bus on the main carriageway enhances the possibility of a rear-ending crash.

In order to prevent such crashes -

i. Bus stops should follow design specifications as illustrated below to ensure the safety and comfort of commuters waiting for the bus.
ii. The layout of the pick-up bus stop should follow the specifications of IRC 80: 1981.

iii. The bus stop should be easily accessible from the pedestrian sidewalk and crossing facilities.

iv. A gap of 300 meters from the tangent point of intersection to the start/end of the layby will be desirable, particularly at junctions with main roads. In other cases, the distance may be relaxed to a certain extent having regard to the local conditions. At the minor intersections (e.g., junctions with village roads), the distance of 60 meters may be accepted as a special case. However, if a substantial volume of buses is to turn right at the intersection, it is necessary that

v. The bus stop should be located sufficiently ahead of the intersection so that the buses can be maneuvered easily from the pick-up stop on the left-hand side to the extreme right lane for turning.

3.3 Crashes due to haphazard movement of pedestrians on the road

Pedestrians may not be permitted to move on the space designated for vehicular traffic with speed limit more than 40 km/h. This shall be ensured by the provision of proper and dedicated pedestrian facilities.

Pedestrian facility shall be designed with the following factors

i. The pathway shall be continuous and unbroken.

ii. The pathway shall be easily accessible to differently-abled

iii. The pathway need not be continuous with the road and may be treated as a separate entity. However, it shall fully suffice the needs of all pedestrians.

iv. There shall be no objects on the pathway to limit the width.

v. At locations where the pathway is to cross minor roads, the pathway shall be leveled and the road shall rise to meet the pathway through a speed table.

vi. At locations where the pathway is to cross major roads, a zebra crossing shall be present

vii. At locations where the pathway is to cross multilane bi-directional traffic, there shall be safe refuge space for the pedestrians or the crossing shall be signalised for the safe movement of pedestrians.

viii. Illumination shall be provided for pedestrian pathways. The illumination need not be on high mast and may be limited to ensuring the visibility of the pathway.

In many cases, haphazard movement is seen during crossing, especially at intersections. Tactical redesign of a location, also referred to as Tactical Urbanism Trials in some literature, shall be undertaken if pedestrian and non-motorised traffic are the primary victims. Tactical redesign shall be undertaken for locations with:

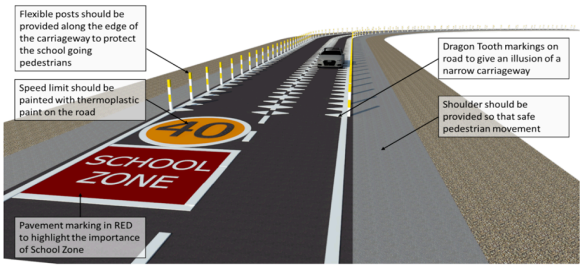
i. High volume of pedestrian crossing at intersections,

ii. Haphazard movement of pedestrians along or across the road,

iii. Haphazard movement and unsafe mix of motorised traffic and non-motorised traffic in the same space.

3.4 Pedestrian crashes (school children) due to unsafe walking on the highway

Areas near a school require absolutely low speeds. School children are more prone to commit mistakes while negotiating with highway traffic. The absence of designated pedestrian crossing and sidewalk facilities near a school increases the risk of fatalities.



In order to prevent crashes at school zones, the following should adhered to:

i. All schools and institutional areas along the highway should be provided with raised pedestrian crossings at every 100-150 m. These crossings should be accompanied by advance warning signs stating, ‘speed breaker ahead’, ‘school/hospital area’, and 30 km/hr speed limit.

ii. In the case of high-density corridors where the setback from the highway is less than 6 m, traffic calming devices should be used to restrict corridor speed between 30 to 50 km/hr.

iii. 2.5 m wide continuous paved shoulders should be provided along with a minimum of 1.5 m wide raised footpaths on both sides of the highway.

iv. Raised pedestrian crossings at every 100-150 m at all schools, hospitals, and institutional areas along the highway.
v. Advance warning signs stating, ‘speed breaker ahead’, ‘school area’, and 40 km/hr speed limit should be provided.
vi. The school zone should be 100 meters on either side of the school.
vii. Absence of demarcation of the school zone on the pavement with letters "SCHOOL ZONE" in white and within a red background.
viii. Pedestrian underpass/foot over bridge shall also be provided within a distance of 200 m from a school.

3.4 Pedestrian crashes while Crossing

Pedestrian unsafe crossing behavior such as not using the designated crosswalks, jaywalking, signal violation, distraction while crossing increases the likelihood of pedestrian-vehicular crashes. In addition, the lack of pedestrian crossing facilities such as the absence of zebra crossing, FOB, or underpass increases the risk of pedestrian-vehicular crashes.

In order to prevent such crashes, the following guidelines should adhere to:

i. Provision should be made for providing designated pedestrian crosswalks with a ‘pedestrian crossing sign’.
i. A continuous footpath and safe crossing facilities should be provided along with the built-up areas, school zones, and hospital zones.
ii. To improve visibility during the night, road studs should be provided along the pedestrian crosswalk. Pedestrian sidewalk and crosswalk facilities should be continuous and interconnected to other pedestrian facilities.
iii. Provision of installation of rumble strips at 10 m to 20 m before the pedestrian crossing.
iv. Absence of demarcation of the school zone on the pavement with letters "SCHOOL ZONE" in white and within a red background.
v. Pedestrian underpass/foot over bridge shall also be provided within a distance of 200 m from a school.

3.5 Lack of pedestrian Safety Treatment at Hospital Zone

Areas near a hospital require absolutely low speeds. The absence of designated pedestrian crossing and sidewalk facilities near a hospital increases the crossing risk as well as the chances of fatalities near a hospital. The presence of an emergency lane near a hospital is also needed to allow the non-interrupting movement of ambulances.

i. In order to prevent crashes near hospitals, following guidelines should be adhered:

ii. All hospital areas along the highway should be provided with raised pedestrian crossings at every 100-150 m. These crossings should be accompanied by advance warning signs stating, ‘speed breaker ahead’, ‘school/hospital area’, and 30 km/hr speed limit.

iii. In the case of high-density corridors where the setback from the highway is less than 6 m, traffic calming devices should be used to restrict corridor speed between 30 to 50 km/hr.

iv. 2.5 m wide continuous paved shoulders should be provided along with a minimum of 1.5 m wide raised footpaths on both sides of the highway.

v. Raised pedestrian crossings at every 100-150 m at all schools, hospitals, and institutional areas along the highway.

vi. Advance warning signs stating, ‘speed breaker ahead’, ‘hospital area’, and 40 km/hr speed limit should be provided.

vii. The ‘hospital zone’ pavement marking should be 100 meters on either side of the hospital.

viii. An emergency lane for an ambulance should be provided at the hospital zone for the non-interrupting movement of the ambulance.

ix. Pedestrian underpass/foot over bridge shall also be provided within a distance of 200 m from a hospital.

Section 13 – Sideswipe Crash

1. SCOPE

This section of the code discusses the various factors due to which sideswipe crashes occur. It also discusses the steps that can be taken to prevent such crashes.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Sideswipe crash due to poor visibility of highway at night

One of the major reasons for sideswipe crashes on the highway at night hours is due to poor visibility.

In order to prevent such crashes road visibility of the roads should be increased with the help of retro-reflective delineators and road signages. The installation of the same shall be based on the standards mentioned in IRC 67:2012 and IRC 79: 2019.

3.2 Sideswipe crashes due to lane narrowing or sudden lane drop

Sideswipe crashes also occur due to the unavailability of indicators or warnings about lane narrowing. In order. To avoid such crashes the risk factor should be addressed/ or rectified with the help of lane marking or by kerb markers, which shall indicate lane narrowing. The standard for laying such lane markers is mentioned in IRC 99:2018, Figure 2.2 (Page 7)

Section 14 – Crash Due to Fatigue

1. SCOPE

This section of the code discusses one of the most concerning factors, 'fatigue'. The section scopes out ways to prevent such crashes.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPES OF RISK FACTORS

3.1 Crash due to fatigue (Drowsiness)

One of the leading causes of truck crashes is driver fatigue. Truck drivers tend to work long, monotonous hours and prefer to drive late at night, as a result, the likelihood of crashes due to driver's fatigue and drowsiness increases.

In order to prevent such crashes provision of truck rest stop and truck lay-bye should be constructed as per IRC 12:2016 and IRC SP 87:2019, Section 12.6 . Reference to the same can be found in subsection 3.21 of Part IV of this Part.

As a part of the ZFC initiative, two truck rest stops were constructed on MPEW by Maharashtra State Road Development Corporation. The truck stops provided a safe space for truck drivers to take rest and sleep. This led to a marked fatality reduction.

Section 15 – Hydroplaning Related Crash

1. SCOPE

This section of the code discusses crashes that occur due to hydroplaning. The section highlights the various steps that can be taken to prevent such crashes.

2. TERMINOLOGY

The definition of the terms used in this section are given in Part 1 of this code.

3. TYPE OF RISK FACTORS

3.1 Crash due to hydroplaning

Chances of road crash increase when there is the pooling of water due to poor drainage.

In order to prevent such pooling of water on the roads, standard hydroplaning should be done. Such planning should entail the construction of a minimum longitudinal gradient of 0.3%. For high type bituminous surfacing for non-kerbed roads the drainage slope should be between 2.0-2.5% and for roads with kerbs within 2.5%. For cement concrete surfacing for non-kerbed roads drainage slope should be between 2.0%-2.5% and for roads with kerb within 2.5%.

Safety requirements mentioned in IRC SP 42:2014, Section 4.4.1 and Crossfall/ Camber 4.4.2 (Page No.13)

Annexure

(Treatment of Repetitive Road Engineering Issues)

1. Absent Crash Barriers

Crash barriers are essential safety installations on roads intended to prevent vehicles from leaving the roadway in dangerous situations.

Absence of crash barriers along high-speed corridors is associated with the following risk factors: (i) Rollovers, (ii) Run-offs, (iii) Head-on collisions, and (iv) Fixed-object collisions.

1.1 Installation of Crash Barriers[5]

Crash barriers are strategically placed in areas such as sharp curves, near bridge approaches, and where the road is adjacent to steep embankments or hazardous obstacles like poles and bridge structural elements.

1.2 Installation Warrants[1]

a) If the embankment slope is greater than 3:1.
b) To shield non-traversable hazards and fixed objects like rough rock cuts, large boulders, and water bodies deeper than 0.6 meters.
c) At bridge approaches to transition smoothly between road barriers and bridge railings.
d) At locations where highways are adjacent to populated areas, such as schools, businesses, or residential zones.
e) If ditches near the roadway present a hazard that cannot be safely traversed by an errant vehicle.
f) Near steep grades where vehicles could lose braking functionality.
g) At particular locations with a history of crashes due to specific issues like sharp curves or nearby hazards.

1.3 Types of Crash Barriers[1]

(a) Rigid Barrier: It is constructed from materials such as concrete. It possesses minimal flexibility and is designed to withstand significant impact forces without deforming or yielding. Rigid barriers provide robust protection but may transfer higher impact forces to the vehicle occupants upon collision.

(b) Semi-Rigid Barrier: It is constructed using materials like steel or wood. It offers a moderate level of flexibility, able to absorb some impact energy while still providing structural integrity. Semi-rigid barriers strike a balance between rigidity and flexibility, offering adequate protection with reduced potential for vehicle rebound.

(C) Flexible Barriers: It is often made of materials like cable or plastic. It exhibits high flexibility, capable of absorbing impact energy and deforming upon collision. Flexible barriers are designed to reduce the severity of impacts by safely redirecting

[5]**Source:** *IRC: 119-2015 Guidelines for Traffic Safety Barriers*

vehicles and minimising the risk of injury to occupants.

1.4 Functions of Crash Barriers[1]

(a) Road Edge Barriers:

These are installed along the edge of roadways to protect errant vehicles from steep off-road drop-offs, fixed objects, or hazardous terrain.

(b) Median Barriers:

Positioned in the median strip of divided highways to prevent vehicles from crossing into oncoming traffic lanes during out-of-control situations.

1.5 Applicability based on Road Types[6]

Road type	Applicability	
	Edge Barriers	Median Barriers
Expressway	Yes	Yes
NH	Yes	Yes
SH	Yes	No*
MDR and other roads	Yes	No

1.6 Specification for Safety Barriers[7]:

a) The concrete barriers should be made from reinforced cement concrete with a minimum grade of M40 and aggregates not exceeding 12 mm.
b) Metal barriers, including posts and W-Beam sections, must adhere to specific testing standards such as EN 1317-2 or NCHRP 350.
c) Wire rope (cable) barriers should meet European EN 1317-2 standards, with cables made of galvanised steel prestressed to specific tolerances and anchored using concrete blocks.

1. Damaged Crash Barriers

Crash barriers can be damaged due to various reasons, including vehicle impacts, environmental conditions like corrosion from salt and water, and mechanical wear from vibrations and frequent impacts.

Damaged crash barriers are associated with the following risk factors: (i) Rollovers, (ii)

[6]*May be required in case of 4-lane divided carraigeways and above.*
[7]***Source:*** *IRC: 119-2015 Guidelines for Traffic Safety Barriers*

Run-offs, (iii) Head-on collisions, (iv) Fixed-object collisions, and (v) Object Impailment.

2.1 Assessment of Damage.

Develop a detailed checklist for assessing various types of damages, including corrosion, deformation, loosening of fixtures, and visible signs of impact.

2.2 Immediate Temporary Measures

a) Set up temporary barriers or signage to warn motorists of the damaged barrier.
b) Use cones, flashing lights, or barriers to redirect traffic away from the damaged section until repairs can be completed.

2.3 Repair Techniques

a) Replace specific components of the barriers, such as posts, rails, or panels, rather than the entire installation if they are identified as the only damaged elements.
b) Use welding for metal barriers and straightening techniques where applicable.

2.3 Maintenance of Traffic Safety Barriers

a) Routine Maintenance

Routine maintenance should include occasional cleaning and painting, with minimal ongoing requirements when using treated wood posts and galvanised steel.

b) Collision Maintenance

Repairs due to vehicle impacts form the major part of maintenance costs. The design should facilitate quick repairs, using standardised components to simplify operations and minimise road closure times.

3. Inappropriate Termination and Transition of Crash Barriers

It refers to the improper design, placement, or construction of the ends and transitions of roadside barriers intended to mitigate the severity of vehicle collisions.

Inappropriate termination and transition are associated with the following risk factors: (i) Rollovers, (ii) Run-offs, (iii) Vehicle snagging, and (iv) vehicle rebound.

3.1 Appropriate Termination of Crash Barriers[8]

(a) Safe Distance: The barriers should either end at a safe distance from the lane or be equipped with an end treatment that reduces the risk of spearing vehicles

(b) End Treatment (Approach Side): The approach side of the crash barrier should be provided with a Modified Eccentric Loader Terminal (MELT) arrangement.

[8]***Source:*** *IRC: 119-2015 Guidelines for Traffic Safety Barriers*

(c) End Treatment (Trailing Side) A Trailing Terminal (TT) arrangement is recommended for the departure sides.

3.2 Appropriate Transition of Crash Barriers[4]:

Transitions are crucial where different types of barriers meet or where barriers connect to bridge railings. The transitions must be designed to maintain the integrity and performance of the barrier system, preventing vehicle snagging or redirection issues.

Ensure that all barrier sections are well connected and that transitions between different types or strengths of barriers do not create gaps or weak points.

For example, transitioning from a high-profile median barrier to a roadside barrier requires careful alignment and anchoring to maintain continuity and performance).

4 Absent and Faded Pavement Marking

Pavement markings are defined as lines, patterns, and words (except road signs) which are applied or attached to the carriageway or kerbs or to objects within or adjacent to the carriageway for controlling, warning, guiding, and informing the road users

The absent or faded pavement markings can lead to confusion among drivers, reduced compliance with traffic rules, and an increased likelihood of lane departure or improper manoeuvres.

4.1 Types and Materials of Road Markings[9]

(a) Thermoplastic Markings: Frequently used for their durability and retro-reflective properties. Depending on traffic volume, they solidify quickly at ambient temperatures and have a service life of 2 to 3 years.

(b) Paint-Based Markings: Include solvent-borne and waterborne options

[9]***Source:*** *IRC: 35-2015 Code of Practice for Road Markings*

suitable for temporary or less durable requirements.

(c) Cold Applied Plastics and Preformed Tapes: Offer durability and are used in high-traffic areas or for enhanced visibility and durability.

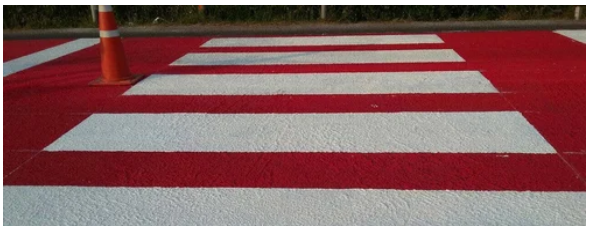
4.2 Colour Pattern for Markings[10]

(a) White: Most common for general road markings due to high visibility.

(b) Yellow indicates no crossing and manages traffic restrictions.

(c) Blue/Green: Special purposes like public transport lanes or bicycle lanes.

(d) Red/Purple: Signify hazardous areas or conflict zones between pedestrian and vehicular traffic.



4.3 Applications and Placement[6]

(a) Longitudinal and Transverse Markings: .Guide traffic movement and control lane discipline.

(i) Broken lines: Can be crossed by vehicles.

[10]**Source:** *IRC: 35-2015 Code of Practice for Road Markings*

(ii) Continuous lines: Should not be crossed, indicating areas where overtaking or lane changes are prohibited.

(b) Transverse Markings: Control traffic at intersections, pedestrian crossings, and other areas requiring vehicular control.

(i) Stop lines, yield lines, and pedestrian crosswalks: Essential for safety and order, always paired with appropriate signage to ensure compliance.

(c) Hazard Markings: Alert drivers to potential hazards and guide traffic around or through hazardous areas.

(i) Chevron and diagonal markings: Used for traffic merges and diverges.

(d) Prohibitory markings: Indicate areas where vehicle crossing is prohibited.

(e) Block Markings (BM): Highlight areas with specific functions or hazards. Essential for warning the drivers about the conflict zone.

(f) Arrow Markings: Indicate mandatory directions drivers must follow. They are painted on road surfaces to direct traffic flows, especially at junctions and lane splits.

(g) Directional Markings: Provide directional information and guidance. They indicate messages often used along high-speed corridors and multi-lane roads.

(h) Facility Markings: Identify areas designated for specific types of vehicles or activities., such as for bus lanes, bicycle lanes, and parking spaces designated for disabled individuals.

4.4 Maintenance Protocols

Frequent maintenance is advised for high-traffic areas where markings quickly fade.

It is advised to do regular assessments of wear and retro-reflectivity to determine reapplication needs.

Traffic volume data should guide the maintenance schedules, ensuring markings are always up to standards and reducing the frequency of complete reapplications.

5. Untreated Intersection & Access to the Carriageway

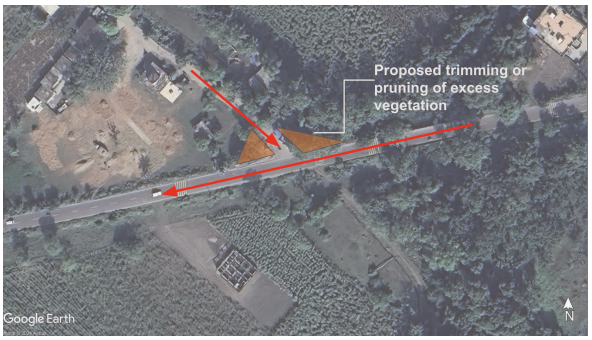
Improper access to highways stems from a variety of factors, including rapid urbanisation fostering haphazard development, resulting in unauthorised access points, deficient urban planning overlooking the necessity for controlled highway access, and lack of enforcement of access management regulations enabling the unauthorised establishment of access points, and the presence of informal settlements near highways, fostering the emergence of access points.

The presence of improper access to highways is generally associated with the following risk factors. (i) Side swipe collisions, head-on collisions, and (iii) pedestrian crashes.

5.1 Treatment of Access Roads:

(a) Clearing Vision Obstructions: Vision obstruction caused by vegetation and structures along highways near access roads impedes drivers' line of sight, limiting their ability to perceive potential hazards and react promptly. The reduced visibility due to vision obstruction can lead to decreased driver perception-reaction time, exacerbating the risk of crashes near untreated access roads.

Therefore, proactive measures such as regular vegetation management and shifting of structures to ensure a minimum triangular stopping sight distance (SSD) of 50 meters for vehicles on the main carriageway are essential to optimise driver visibility and mitigate collision risks effectively.



(b) Installation of Traffic Calming Measures[11]: Traffic calming measures are measures implemented to decrease vehicular speeds at vulnerable locations.

Rumble strips play a crucial role in traffic calming by providing physical and auditory warnings to drivers, prompting them to reduce their speeds. To maximise their effectiveness, installing a minimum of six sets of rumble strips is recommended. These should be made from thermoplastic materials, available in either white or yellow colours, and with varying 5 mm or 7.5 mm thicknesses.

The installation of these rumble strips should be strategically placed at least 50 meters before the approach to access roads. This placement helps in alerting drivers in advance, allowing sufficient time to slow down.

(c) Installation of Traffic Sign Boards[12]:

Installing appropriate informative signboards indicating the presence of access roads, along with speed limit and "go slow" directives, significantly enhances road safety along sections with improper access to the carriageway.

(c) Installation of Streetlights[13]:

Streetlights play a critical role in enhancing road safety, particularly during nighttime and adverse weather conditions. Maintaining a recommended average illumination level of 30 lux on highways significantly improves visibility. This level of illumination facilitates and assists in the early detection of hazardous conditions and ensures continuous safe traffic flow.

5.2 What is an Intersection?

An intersection is a junction or an area of the roadway where two or more roads cross or meet. The three basic types of intersections are the three-leg or T-intersection (with variations in the angle of approach), the four-leg intersection, and the multi-leg intersection.

[11]**Source**: *IRC:99-2018 Guidelines for Traffic Calming measures in Urban and Rural Areas*
[12]**Source:** *IRC: 67-2022 Code of Practice for Road Signs*
[13]**Source**: IS 1944-1 and 2 (1970): Code of Practice for Lighting of Public Thoroughfares

5.2.1 What is an Untreated Intersection

An untreated intersection, also known as an uncontrolled intersection, is a junction without traffic control devices like traffic signals, stop signs, yield signs, or roundabouts to regulate traffic flow. These intersections depend on drivers following basic road rules and yielding to other vehicles or pedestrians as needed. The safety and effectiveness of untreated intersections heavily rely on the responsible behaviour of all road users and their adherence to traffic laws and common driving courtesy. Therefore, these intersections should be redesigned according to the intersection design principles and rules set by the IRC.

5..2.2 What are the different types of Intersections and roads?

There are various types of roads and intersections/junctions, each uniquely distinct. The table below lists different types of junctions and roads, each treated differently based on their specific combinations.

Type of Junction	Road Type
Four-Arm Intersection (Signalized)	NH & Village Road
Four-Arm Intersection (Un-signalized)	NH & Arterial Road
Three-Arm Junction (Signalized)	NH & Minor Road
Three-Arm Junction (Un-signalized)	Arterial & Sub-Arterial road
Roundabout	Arterial & Sub-Arterial, and Minor road
Stretch	Arterial & Minor road
Bridge	Neighbourhood roads
Two U-turns	Sub-arterial and minor road
Median Gap	Collector road
	NH & Sub-Arterial

5.2.3 How to redesign an intersection?

While redesigning an intersection, the first step is to adhere to the codes established by the Indian Roads Congress (IRC), the apex body of highway engineers in India. These IRC codes provide a framework for all elements of the road system, including geometric design, pavement structure, drainage systems, etc.

5.2.4 Key issues on an untreated intersection

- Lack of safer public realm
- Absence of designated boarding and alighting zones

- Lack of speed reduction measures
- Absence of clear signage
- Lack of lane demarcations
- Uneven and irregular road surfaces(potholes)
- Incorrect road geometry
- Absence of traffic channelising devices
- Lack of dedicated parking space that promotes Illegal parking on the carriageway or footpath
- Encroachment by vendors, hawkers, shopkeepers etc.
- Lack of illumination

5.2.5 Recommendations to treat these intersections/junctions/stretches

A. Create safe pedestrian realm

- Construct Continuous Footpaths: Ensure footpaths are at a level 150 mm above the carriageway (IRC:103-2012, Section 6.1.2).
- Secure Entry and Exit Access: Use concrete bollards with a clear gap of 1200 mm between them, ensuring universal accessibility (IRC:103-2012, Section 6.11.4).
- Provide Ramps: Install ramps at all access points with specified gradient/slope (IRC:103-2012, Section 6.2.3).
- Crossings: Paint crossings with thermoplastic material, with a minimum width of 2-4 m (IRC:103-2012, Section 6.7.3.1).and it should be connected to pedestrian pathways.
- Provide Pedestrian Crossings: Depending on PCU, provide at-grade crossings, subways, or FOBs (IRC:05-2015).
- Elevated Pedestrian Crossings: At stations, elevate crossings to the height of the adjacent footpath, with a slope of 1:10 gradient for buses.
- Demarcate Cycle Tracks: As per IRC:11-2015, with appropriate shading/plantation
- Mark Stop Lines: Clearly mark stop lines to regulate and organize vehicle flow effectively (IRC:35-2015, Section 6.1.7).
- Median extension: The median width (distance between the inner edges of the carriageway) should be 2.5 metres, including a kerb shyness of 0.50 metres on each side. Median and median drainage should be provided according to IRC:SP:84.
- Provide Refuge Spaces for Pedestrians: Refuge spaces must be level with the carriageway and within medians to ensure smooth pedestrian movement, including accessibility for people with disabilities. According to IRC:103-2012, the recommended width of pedestrian refuges to accommodate a wheelchair or pram is 2 metres. These refuge spaces should be secured from vehicles using bollards, as specified in the same guideline.

B. Create efficient Public infrastructure

- Utilize Residual Space: Dedicate space for parking and bus stops.
- Dedicated Parking Space: Provide based on carriageway width and requirement (IRC: SP 12-2015).
- Bus Stops: Place bus stops 40-45 m before the intersection (IRC:70-2017).
- Intermediate Public Transport (IPT) Stands: Provide stands for auto rickshaws, cycle rickshaws, and taxis near bus stops to facilitate last-mile connectivity (IRC:70-2017).

C. Install Speed Calming measures

Speed calming measures aim to lower vehicle speeds, thereby reducing conflicts and the likelihood of crashes These measures utilise various horizontal and vertical traffic calming devices such as lane narrowing, curb extensions, chicanes, rumble strips, speed humps, and raised crossings. Among these, vertical shifts in the roadway like rumble strips, speed humps, and raised crossings, strategically implemented, not only help manage traffic flow but also discourage drivers from travelling at excessive speeds.

- Thermoplastic Material for TBM: Paint TBM with thermoplastic material, with raised sections 20 to 30 mm high, 200-300 mm wide, and spaced about 1 meters centre to centre. (IRC:99-2018, Section 2.3.3.3, Section 2.3.3.4) These rumble strips can be installed on National Highways (NHs) and State Highways.
- Speed table top: Raised crossings or speed tables are implemented to mitigate conflicts among various types of traffic, such as cars, motor vehicles, cyclists, and pedestrians. These are primarily deployed at minor junctions, property access points, and entrances to service roads, ensuring comfort, convenience, and safety for all users. These structures include vertical deflections to lower traffic speeds and flat-topped(5 metres long) sections designed for pedestrian crossings, as outlined in IRC:99-2018. This measure is applied only to urban roads
- Vertical and horizontal signages: Place vertical and horizontal signage at suitable distances from the intersection as specified in IRC 067-2012. Additionally, mark horizontal speed limits using synthetic enamel paint to indicate the proposed speed limit,

beginning 100 metres before the intersection.

- Priority Intersections: At minor-major road intersections, use STOP or GIVE WAY signs/road markings to clarify which road has priority (IRC:66-1976, Section 9).

D. Geometry correction

- Aligning Approach Roads: Ensure approach roads meet the intersection at appropriate angles to improve visibility and reduce the likelihood of collisions.
- Widening Turning Lanes: Ensure turning lanes are wide enough to accommodate vehicles without encroaching into adjacent lanes.
- Traffic Islands: Adhere to the appropriate turning radius for various transportation modes (IRC SP 041).
- Mark Stop Lines: Clearly mark stop lines to regulate and organise vehicle flow effectively (IRC:35-2015, Section 6.1.7).

E. Site Illumination

- Install Street Lights: Install street lights on the intersection as per IS: 1944 (Part V)-1981 standards.
- Traffic Signals Lights: Equipped with their own lighting to ensure visibility and clarity of signals during nighttime or low visibility conditions.
- Reflective Materials and Markings: Retro-reflective materials used on traffic signs, pavement markings, and delineators to enhance visibility under vehicle headlights.
- Delineators: Installations of delineators as per IRC:79-2019

F. Other Elements

- Vegetation: Pruning of trees/bushes as per IRC:119-2018. To enhance the visibility and site distance.
- Sight Distance: Sight distance for should be referred as per IRC:66-1976, Section 9) for rural highways and IRC:86-1983 for urban highways

Compact junctions decrease pedestrian exposure to traffic, thereby lowering the risk of crashes.

6. What is a Untreated Gap-in-Median

An untreated gap-in-median refers to a section of the median on a highway (NH or SH) that is left open and lacks proper traffic control measures or infrastructure. This gap is not equipped with necessary safety features such as barriers, traffic signals, signage, or designated crossing points. It is essentially an unregulated opening in the median that allows for crossing between the opposing lanes of traffic without any safety provisions.

6.1 Why Untreated Gaps-in-Median Are Dangerous?

Probable Conflicts: Vehicles using these gaps for U-turns or crossing the highway may collide head-on with oncoming traffic, especially at high speeds and vehicles may enter and exit the gap unpredictably, leading to confusion and probable crashes

Pedestrian Risks: Pedestrians might use these gaps to cross busy highways, significantly increasing the risk of being hit by fast-moving vehicles.

Traffic Flow Disruptions: Unregulated use of median gaps can disrupt the smooth flow of traffic, causing congestion and increasing the risk of rear-end collisions.

Driver Confusion: Lack of proper signage can confuse drivers about whether the gap is a legitimate crossing point, leading to sudden stops or unsafe manoeuvres.

6.2 Rectification Methods

Median Barriers installation : These are used to separate opposing directions of traffic on a highway. Median barriers are designed to redirect vehicles striking either side of the barrier, keeping motorists safe from head-on collisions. Erecting continuous barriers such as guardrails or concrete dividers to prevent unauthorized crossing.

Controlled Intersections: Converting necessary gaps into controlled intersections with traffic lights, signs, and marked pedestrian crossings to manage safe crossings.

Clear Signage: Installing clear and visible signage (vertical and horizontal) to inform drivers of no U-turns, pedestrian crossings, or other restrictions.

Speed calming Installation: Installation of continuous Rumble strips, speed humps , speed tables and speed limit signages can significantly improve road safety by reducing speed and hence reduce the risks

associated with these critical points on highways.

7 Absent/Inadequate pedestrian facilities

7.1.Absen /Discontinuous Pedestrian Footpaths

The absence or discontinuity of pedestrian footpaths poses significant safety risks and accessibility issues, particularly in urban and suburban areas. Pedestrian footpaths are essential for ensuring the safety and mobility of pedestrians, providing a dedicated space for walking separate from vehicular traffic. Without continuous footpaths, pedestrians are forced to walk on the road, increasing the likelihood of accidents and impeding safe, efficient transportation.

7.1.1 Importance of Continuous Pedestrian Footpaths

Safety: Footpaths provide a safe space for pedestrians, reducing the risk of accidents involving vehicles. They are crucial in urban areas with high pedestrian traffic and in school zones where children walk to and from school.

Accessibility: Continuous footpaths ensure accessibility for all individuals, including those with disabilities, the elderly, and parents with strollers, allowing safe and easy movement throughout urban and suburban areas.

Encouraging Walking: Well-maintained and continuous footpaths encourage walking as a mode of transportation, promoting healthier lifestyles and reducing vehicular traffic and pollution.

7.1.2. Standards for Pedestrian Footpaths

Width: The width of pedestrian footpaths should accommodate expected pedestrian traffic. In high-traffic areas, footpaths should be at least 1.8 meters wide, while lower-traffic areas can have footpaths with a minimum width of 1.2 meters.

Surface Material: Footpaths should be constructed with durable, non-slip materials such as concrete or asphalt. The surface should be smooth and even to prevent tripping hazards and ensure accessibility for wheelchairs and strollers.

Continuity: Footpaths should be continuous and uninterrupted. Gaps or discontinuities force pedestrians onto the road, increasing the risk of accidents. Footpaths should seamlessly connect across driveways, intersections, and entrances to buildings.

16.3 Enhancements and Maintenance

Regular Maintenance: Regular inspections and maintenance are crucial to ensure footpaths remain safe and usable. Cracks, uneven surfaces, and obstructions should be promptly repaired to prevent accidents and ensure accessibility.

Pedestrian Crossings: Clearly marked and signalised pedestrian crossings should be provided at regular intervals, especially at busy intersections, to ensure safe crossing points for pedestrians.

Lighting: Adequate lighting along footpaths enhances safety, especially during nighttime. Well-lit footpaths reduce the risk of accidents and enhance personal security.

Amenities: Adding amenities such as benches, trash bins, and shade structures can improve the usability and comfort of footpaths, encouraging more people to walk.

Absent or broken pedestrian guard rails can pose significant safety risks, especially in urban areas with heavy foot traffic. These guard rails, typically installed along sidewalks and pedestrian crossings, serve several critical functions

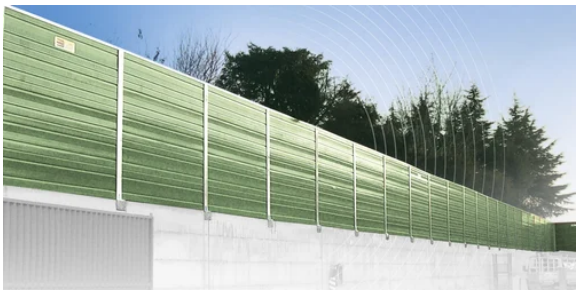
7.2 Types of Pedestrian Guardrails for Highways

Crash-Resistant Barriers Heavy-duty barriers Installed along highways to prevent vehicles from veering into pedestrian paths, often found on overpasses and near highway exits.

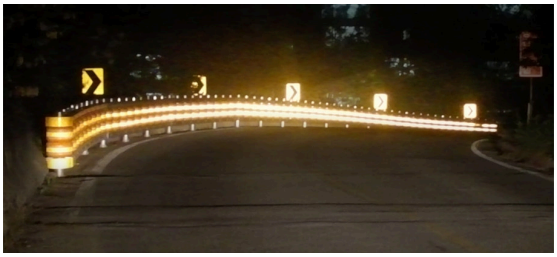
Bridge and Overpass Railings High-strength metal or concrete railings used for pedestrian safety crossing over highways, preventing accidental falls or collisions with vehicles below.

Median Barriers with Pedestrian Guardrail

Barriers placed in the median strip of highways with integrated pedestrian walkways or crossings Facilitate safe pedestrian crossings in areas where highways split urban or suburban areas.



Sound Barrier Walls with Integrated Sound barriers designed to reduce noise pollution, with built-in guardrails to protect pedestrians rails, Common along highways adjacent to residential areas, combining noise reduction with pedestrian safety.



High-Visibility Railings

Guardrails with reflective materials or embedded lighting to enhance visibility at night or during adverse weather conditions.Ensures pedestrian safety in low-visibility conditions, particularly near highway entrances and exits.

7.3 Consequences of Absent or Broken Guardrails

Increased Accident Risk: Without functional guard rails, pedestrians are more vulnerable to traffic crashes, particularly in busy or high-speed traffic junctions/road stretches.

Uncontrolled Crossing: Pedestrians may cross roads at unsafe points, increasing the probability of crashes.

7.4 IRC Guidelines for Pedestrian Guardrails

- Guardrails should be made of durable materials such as steel, aluminum, or reinforced concrete to withstand weather and impact.
- The design should prevent climbing and slipping, with no sharp edges or protruding parts.
- The standard height for pedestrian guardrails is typically between 1.0 to 1.2 metres.
- The length of guardrails should be adequate to cover the entire area where pedestrian movement needs to be controlled.
- Guardrails should be clearly visible to both pedestrians and drivers. Reflective strips or paint can enhance visibility, especially at night.
- Guardrails should be placed at critical points such as pedestrian crossings, near schools, along sidewalks adjacent to high-speed roads, and around hazardous areas.
- Guardrails should not obstruct pathways for disabled individuals and should comply with accessibility standards.

Installing pedestrian guardrails as per IRC guidelines requires careful planning, material selection, and adherence to safety standards. By considering the specific requirements of different road types, pedestrian safety can be ensured, thereby reducing crashes and enhancing the overall efficiency of the road network.

7.5. Pedestrian Crossing

A pedestrian crossing, also known as a crosswalk, is a designated point on a road where pedestrians are given priority to cross the street. These crossings are marked to alert both pedestrians and drivers to areas where pedestrian traffic is expected, thereby enhancing safety and organisation on the roads. Pedestrian crossings can vary in design and regulation, but they generally fall into the following types:

- Marked Crosswalks
- Unmarked Crosswalks
- Signal-Controlled Crosswalks:
- Pedestrian Overpasses and Underpasses:
- Pedestrian Refuge Islands
- School Crossings
- Raised Crosswalks

7.5.1 Installation of pedestrian crossing

A zebra crossing is a clearly specified pedestrian track across the carriageway and is delineated with the help of alternate black and white stripes, which should have embossed texture for easy detection by persons with vision impairment. Thermoplastic paint with + 5 mm embossed texture can be used and raised pedestrian crossings (table top) be provided. A zebra crossing must always be accompanied by a “STOP” line as per IRC:35-1970 ‘Code of Practice For Road Markings

Width of and distancing of zebra crossing

The width of the zebra crossing must be adequate and should generally lie within a range of 2-4 m. For divided carriageways, the crossing should, as far as possible, proceed uninterrupted through the median strip. In the event of the median strip being used as pedestrian refuge, adequate width of median must be provided. In case of raised medians, such

portions could be suitably depressed with kerb height not exceeding 150 mm. A range of 80 m - 250 m to be maintained between consecutive crossings.

Absent Pedestrian Crossing

Inaccessible Pedestrian Crossing

Faded Pedestrian Crossing

Optical illusion Crossing

7.6 Consequences of Absent, Faded, Inaccessible, or Discontinuous Pedestrian Crossings

Higher Crash Rates: Without clear and visible pedestrian crossings, pedestrians are at a higher risk of being hit by vehicles. Drivers may not be aware of areas where pedestrians are likely to cross, leading to an increase in accidents.

Inaccessibility: Faded or inaccessible crossings make it difficult for people with disabilities, the elderly, and children to navigate safely. This can limit their mobility and access to essential services.

Unpredictable Crossing Behavior: Pedestrians are more likely to cross at unpredictable locations when designated crossings are absent or unclear. This can disrupt traffic flow and increase congestion as drivers must slow down or stop unexpectedly.

Decreased Walkability: Poor pedestrian infrastructure diminishes the walkability of urban areas, making them less attractive for residents and visitors. This can negatively impact local businesses and reduce community engagement.

Higher Maintenance Costs: Delaying the repair and maintenance of pedestrian crossings can lead to more significant deterioration over time, resulting in higher long-term maintenance and repair costs.

7.7. Mitigation

Ensure all pedestrian crossings are clearly marked, regularly maintained, and accessible to all users.

Mark clear stop lines along the direction of traffic movement to regulate and organize vehicle flow effectively.(IRC:35-2015)

Implement continuous and connected pedestrian pathways that facilitate safe and efficient pedestrian movement.

Use high-quality materials and designs that enhance the visibility and durability of pedestrian crossings, thereby improving safety for all road users.

By prioritising pedestrian infrastructure, cities can enhance safety, mobility, and overall urban livability.

8. Untreated Hard Structures

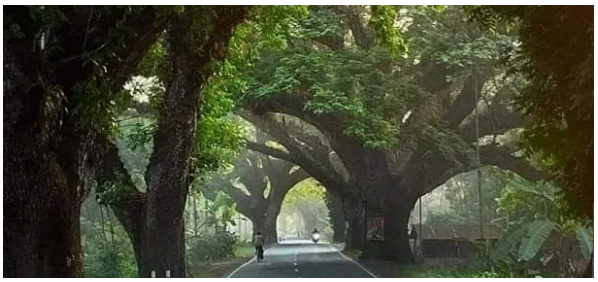
Untreated hard structures pose significant risks on highways, potentially leading to object impact collisions and compromising road safety. These structures include rigid elements such as concrete barriers, bridge abutments, and retaining walls, which, if left untreated, can increase the likelihood of accidents and injuries.

8.1 Types of Hard Structures

(a) Concrete Structures: constructed along the median and roadside, concrete structures can pose hazards if improperly located.

(b) Bridge Abutments: Rigid structures supporting bridge ends, bridge abutments require careful treatment to minimise collision risks.

(c) Trees: Untreated trees along highways can pose collision risks if located too close to the roadway, necessitating appropriate treatment measures.



(d) Light Poles: Light poles, if not properly treated, can present collision hazards for drivers, especially in low-light conditions.

8.2 Treatment of Hard Structures

(a) Relocation: Where feasible, relocating hard structures away from the roadside or median can reduce collision risks and enhance overall safety.

(b) Hazard Markers[14]: Installing appropriate hazard markers such as reflective delineators or chevron signs to increase visibility and

[14]***Source***: *IRC: 79-2019 Recommended Practice for Road Delineators*

alert drivers to the presence of hard structures.

(i) Design of Hazard Markers:

Type of Sheeting: Hazard markers are required to be made with Type XI sheeting conforming to IRC:67-2022 guidelines.

Pattern: They should feature alternating black and yellow stripes sloping downward at a 45° angle towards the side of the obstruction on which the traffic is to pass.

Application and Placement

(ii) Placement: These markers should be erected immediately ahead of the line of obstruction, such as just where the bridge rail starts on a narrow bridge.

(c)Impact Attenuators: Implementing impact attenuators or crash cushions to absorb energy in the event of a collision with hard structures, reducing the severity of impact.

(d) Vegetation Management: Regular pruning and maintenance of trees/bushes near hard structures increases their visibility and reduces the risk of object impact collision.

9. Absent or Damaged Signboards

Sign boards are defined as devices that communicate specific information to road users through symbols, words, or both. They are used to regulate, warn, and guide traffic, providing necessary information that contributes to road safety and efficient traffic management.

Absent or damaged sign boards create confusion for the drivers, which may result in non-compliance with road regulations.

9.1 Installation of Sign Boards[15]

Traffic Signs must fulfil a need, command attention, convey clear and simple meanings, command respect, and provide adequate time for response.

9.2. Classification of Road Signs[10]

(a) Mandatory/Regulatory Signs: Generally circular, with a red border indicating prohibitions or obligations.

(b) Cautionary/Warning Signs: Triangular with a red border, alerting of potential dangers.

[15]**Source:***IRC: 67-2022 Code of Practice for Road Signs*

(c) Informatory Signs: Rectangular, providing directions or data.

9.3 Size of Signs[10]

Different sizes are specified for different road types and conditions, ranging from 600 mm to 1200 mm in diameter, with special provisions for expressways (1500 mm).

9.4 Siting of Signs with Respect to the Carriageway

Signs should be placed at locations where they are easily visible to drivers and can be safely observed without distracting from driving tasks.

9.4.1 Specific Placement Guidelines[10]

(a) Distance from the Road: The bottom edge of signs should be placed at a minimum height.

Kerbed Roads: At least 2.1 meters from the kerb, up to a maximum of 2.5 meters.

Non-Kerbed Roads: At least 2 meters from the road surface, up to a maximum of 2.5 meters.

Pedestrian Areas: A minimum headroom of 2.1 meters where pedestrian traffic is expected.

(b) Lateral Position: Signs on roads with shoulders should be at least 600 mm away from the edge of the pavement.

This can extend up to 3 meters depending on the available right of way. A minimum clearance of 1 meter from the edge of the roadway is recommended for roads without shoulders.

(c) Gantry Signs: When using overhead gantries, ensure that signs are placed at least 7 meters away from the nearest traffic lane to prevent any hazard from protruding structures.

(d) Multiple Signs

Successive signs should be spaced adequately to prevent visual clutter and confusion. The recommended minimum distance between two signs varies based on the road type:

Highways: A formula of 0.6 times the road's design speed (in kilometres per hour) meters apart.

Urban Roads: A fixed distance of at least 20 meters apart.

9.5 Orientation of Signs

(a) Right Angles to Traffic: Generally, signs should be placed at right angles to the direction of travel of approaching traffic. .

(b) Adjustments for Visibility: In certain circumstances, where light reflection from the sign face reduces legibility or in cases of specific road geometries (like curves), the signs may need to be turned slightly away from the road..

(c) Placement on Curves: On horizontal curves, signs should not be fixed normal

(perpendicular) to the carriageway. Instead, the placement angle should be determined regarding the course of approaching traffic to ensure that the signs remain visible and readable as vehicles navigate the curve.

9.6 Visual Specifications for Signs

(a) Retro-Reflective Sheeting: Road signs are often manufactured using retro-reflective sheeting materials that send light back towards the direction of the light source, such as a vehicle's headlight.

Types of Retro-Reflective Materials:

Type I (Engineer Grade): Offers basic retro-reflectivity and is suitable for signs in low-traffic, low-speed areas.

Type III (High-Intensity Grade): Provides higher retro-reflectivity and is used for signs on busier roads where higher visibility at greater distances is required.

Type IV (High-Intensity Prismatic): Advanced retro-reflective technology suitable for high-speed, high-traffic roads, providing superior visibility and durability.

Type XI (Diamond Grade): The highest level of retro-reflectivity available, used for critical signs in fast-moving, complex traffic environments.

(b) Chromaticity Coordinates: The colour of signs is defined by specific chromaticity coordinates that adhere to the CIE (Commission Internationale de l'Eclairage) 1931 Standard Colorimetric System..

(c) Luminance Factor: Minimum Luminance factors include 27% for white, 15% for yellow, and 2.5% for red, with fluorescent colours like yellow-green at 60%, ensuring that signs are effective in various lighting conditions.

9.7 Maintenance and Repair of Damaged Sign Boards

(a) Damage Repair: Signs that are damaged, whether from vandalism, crashes, or wear and tear, should be repaired or replaced immediately to ensure they continue to convey accurate and useful information.

Repairs should adhere to the same standards used for original sign installations. This includes using the same materials and designs to ensure uniformity across all signs.

(b) Retro-Reflectivity Restoration: If the retro-reflective surface of a sign is damaged or has deteriorated over time, it must be replaced to maintain the sign’s effectiveness during nighttime or low-light conditions.

(c) Structural Integrity: Supports and posts should also be inspected and maintained. If a sign’s support structure is damaged, it could lead to the sign falling or becoming incorrectly oriented, which might obscure its message or reduce its visibility.

10..Inadequate Parking Facilities

Inadequate parking facilities present a significant issue for road users and enforcement agencies, leading to congestion, safety hazards, and inconvenience. Without sufficient parking spaces, drivers may resort to unauthorised roadside parking, obstructing the flow of vehicles.

This lack of designated parking areas contributes to traffic congestion and poses critical risk factors such as increased chances of rear-end collisions, reduced visibility for

pedestrians and cyclists, and impeded emergency vehicle access.

10.1 Types of Parking Facilities

(a) Rest Areas: Engineered to provide adequate space for parking, rest areas should be strategically located at regular intervals along the highway to allow drivers to take breaks, with consideration given to sightlines, accessibility, and drainage.

(b) Truck Lay-bays: Designed with sufficient width and length to accommodate large vehicles, truck lay-bays are engineered to minimise disruption to traffic flow while providing safe spaces for trucks to pull over for rest or maintenance.

(c) Toll Plaza Parking: Parking areas near toll plazas are engineered to facilitate smooth ingress and egress for vehicles, with consideration for traffic circulation, signage, and safety measures to prevent congestion and accidents.

10.2 Design Elements of Parking Facilities

(a) Location and Access:

Distance: Typically, parking facilities should be located within a short distance from the highway

(b) Layout Design:

Width: The minimum width of access roads leading to parking facilities should be 6 meters for two-way traffic, with adequate turning radii for larger vehicles.

Minimum parking space dimensions: Standard parking space dimensions should be 2.5 meters wide by 5.5 meters long for cars, with larger dimensions for trucks and buses.

Turning radii: Minimum turning radii at corners should accommodate the largest vehicles expected to use the facility, typically ranging from 12 to 15 meters.

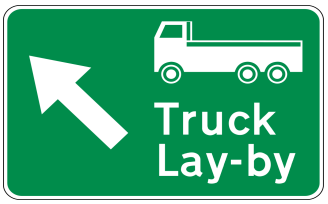
Road Markings[16]: Parking spaces should be clearly marked with paint or thermoplastic markings conforming to IRC: 35-2015 standards.

(c) Signage[17]:

Install signage at entry and exit points indicating parking restrictions, amenities, and

[16] ***Source:*** *IRC: 35-2015 Code of Practice for Road Markings*
[17] ***Source:*** *IRC: 67-2022 Code of Practice for Road Signs*

directional information as per IRC:67-2022 guidelines.



(d) Lighting:

Illuminance levels[18]: The parking spaces and 50 m length of the Project Highway on either side shall be illuminated at night to provide an average illumination of 40 Lux.

11. Absent Illumination

The absence of illumination on highways presents multifaceted challenges, including reduced visibility, compromised pedestrian safety, increased security concerns, and navigation challenges.

Without adequate illumination, drivers face difficulty in identifying roadside hazards and navigating routes, increasing the likelihood of crashes, particularly rear-end collisions, sideswipes, and pedestrian-related incidents.

11.1 Provision of adequate illumination[19]

(a) Classification of Roads and Illumination Levels

Group A1 Roads: These are critical traffic routes where rapid and dense traffic flows. The recommended illumination level is a minimum average of 30 lux.

Group A2 Roads: Includes main roads with mixed traffic conditions, such as city streets and arterial roads, with a recommended minimum average illumination level of 15 lux.

(b) Luminaire Specifications

Cut-off Luminaires: Recommended for Group A1 roads to minimise glare and concentrate light on the road. These fixtures sharply reduce light dispersion above the horizontal plane.

Semi-cut-off Luminaires: Suitable for Group A2 roads, allowing moderate light dispersion suitable for areas with pedestrians and slower traffic.

(c) Uniformity and Quality of Lighting

Uniform lighting is essential for driver visibility and comfort. The uniformity ratio ensures that light distribution across the highway is consistent, preventing dark spots and glare, which can be hazardous.

Uniformity Ratio: Targeting a uniform distribution to ensure that no area along the highway is significantly brighter or darker than the others.

Glare Control: Using luminaire design and placement to control glare effectively is crucial, especially in high-speed traffic areas.

(d) Installation and Siting Guidelines

Height and Spacing: Typically, mounting heights range from 9 to 12 meters, with spacing designed to achieve uniform light distribution.

Siting at Curves and Intersections: Special attention is needed for placing lights at curves and intersections to ensure adequate

[18] ***Source***: *IRC: SP 87-2019 Manual of Specifications and Standards for Six Laning of Highways*
[19] ***Source***: *IS 1944-1 and 2 (1970): Code of Practice for Lighting of Public Thoroughfares*

illumination without causing glare or confusion in visual guidance.

(e) Maintenance and Energy Efficiency

Regular Maintenance: Involves cleaning, timely replacement of lamps, and system checks to maintain optimal lighting conditions.

Energy Efficiency: Encourages the adoption of energy-efficient technologies such as LED lighting, which reduces power consumption and operational costs.

(f) Environmental Considerations

Light Pollution: Measures should be taken to minimise light pollution by using luminaires that direct light downward and by ensuring that lighting is only as intense and as widespread as necessary.

Adaptive Lighting: Consider using adaptive lighting technologies that adjust the intensity based on traffic conditions and time of night to conserve energy and reduce light pollution.

(g) Safety Enhancements

Reflective Markings: Use reflective paint and markers that work in tandem with the lighting to improve visibility and road demarcation.

11.2. Absent Road Delineation

The absence of road delineation on highways can significantly impair nighttime visibility and lane delineation. Road delineators provide critical reflective guidance to drivers, especially in low-light or adverse weather conditions. Without these, the risk of lane departure accidents increases as drivers face difficulty in perceiving lane boundaries and road curvature. This can lead to more frequent and severe collisions, particularly in areas with sharp turns or complex interchanges.

11.3 Provision of Road Delineation

Road delineators are devices that provide visual assistance to drivers, indicating the alignment of the road ahead, particularly during nighttime or adverse weather conditions. They are designed to improve safety by making the road's path clearer, especially in complex locations such as curves, intersections, and areas with changing geometries.

11.4 Types of Delineators

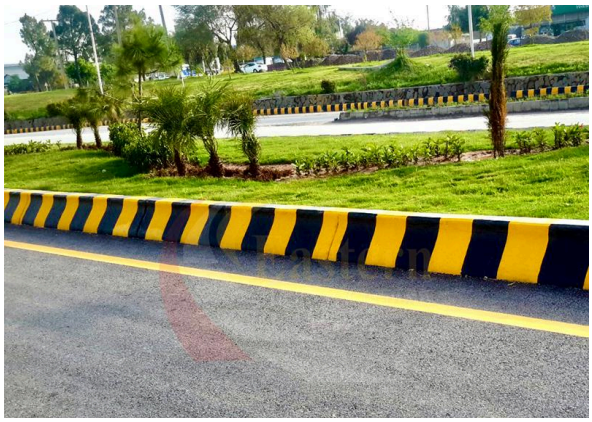
Delineators are classified into four main types:

Roadway Indicators: These delineate the edges of the roadway to guide drivers.

Median Markers: These mark the central divider on roads with medians.

Hazard Markers: These indicate obstructions like guardrails and abutments near the roadway.

Object Markers: These identify hazards and obstructions within the vehicle flow path, such as channelising islands or electric poles.



11.5 Materials Used for Delineators

Materials: Delineators are typically made from durable materials such as mild steel, which is often coated with polyester powder to prevent corrosion. Advanced designs may use thermoplastic bodies for enhanced durability and resistance to weathering, although these can be more expensive.

Visibility Standards: Delineators must comply with specific visibility standards using retro-reflective sheeting. For instance, Type XI sheeting, as per IRC:67 and ASTM D 4956 standards, ensures high nighttime visibility.

Dimensions: Standard delineators are about 800-900 mm in height with a base of 200-300 mm to ensure stable anchoring into the ground.

Colour and Reflectivity: They are designed with black and white retro-reflective sheeting, providing a clear contrast that is easily visible to drivers. Reflective materials should be placed at regular intervals along the delineator to enhance visibility.

11.6 Usage and Installation

Spacing: On high-speed interurban roads, delineators are typically spaced 50-70 meters apart. In rural or less trafficked areas, concrete delineators spaced at similar intervals can serve as a cost-effective alternative.

Work Zones: For temporary guidance in construction or work zones, plastic drums with red and white reflective stripes are used. These temporary delineators must also be securely anchored to prevent displacement.

Site Selection: The decision to install delineators depends on various factors, including the road's importance, traffic volume, prevailing speed, historical crash

data, and specific alignment challenges. They are primarily used on non-urban sections of main roads, especially in curved areas, but can also be deployed in urban settings based on local conditions.

11.7 Regulatory Standards and Guidelines

Design Standards: According to the Indian Roads Congress (IRC), delineators must comply with the standards outlined in IRC:79-2019. The design should incorporate features such as adequate height, colour contrast, and reflectivity to meet visibility requirements.

Maintenance: Regular maintenance is crucial for delineators to ensure they remain effective. This includes cleaning reflective surfaces, replacing damaged or worn-out units, and ensuring that they remain properly anchored.

12. NarrowShoulders

Inadequate road shoulders can pose significant safety risks by limiting safe areas for vehicle recovery, emergency stops, and pedestrian usage. Shoulders provide essential space for drivers to pull over in emergencies, allow for better water drainage, and enhance overall road stability. Without proper shoulders, the risk of accidents increases, particularly in situations where drivers need to avoid obstacles or stop suddenly.

12.1 Importance of Adequate Shoulders

Emergency Stops: Shoulders offer a safe area for vehicles to pull over during emergencies, such as mechanical failures or medical issues, reducing the risk of collisions on the main roadway.

Vehicle Recovery: They provide space for recovering control of vehicles that have veered off the road, preventing potential accidents caused by abrupt returns to the roadway.

Pedestrian Safety: In rural and semi-urban areas, shoulders are crucial for pedestrian traffic, providing a safe walking space away from vehicular lanes.

Drainage: Adequate shoulders improve road drainage, reducing the risk of water accumulation on the road surface, which can lead to hydroplaning and other hazards.

12.2 Standards for Shoulder Design

Width: The standard width for shoulders varies based on road type and traffic volume. Highways typically require shoulders that are at least 2.5 meters wide, while rural roads may have narrower shoulders, about 1.5 meters wide.

Surface Material: Shoulders should be paved with durable materials, such as asphalt or concrete, to support vehicle loads and withstand adverse weather conditions. Gravel shoulders can be used in low-traffic areas but require more maintenance.

Slope: Proper slope design is essential to ensure effective drainage. Shoulders should have a slight slope away from the road to prevent water accumulation and enhance safety.

12.3 Enhancements and Maintenance

Regular Maintenance: Maintaining shoulder integrity through regular inspections and repairs is crucial. Cracks, potholes, and

erosion should be addressed promptly to ensure shoulder effectiveness..

Shoulder Widening Projects: For roads with historically high accident rates, shoulder widening projects can be implemented to provide more space for emergency use and improve overall safety.

13. Signages Covered by Vegetation

Signages obscured by vegetation present significant hazards on roadways, impeding their visibility and effectiveness in conveying critical information to drivers. Vegetation covering road signs can lead to confusion, delayed reactions, and increased risks of accidents. Maintaining clear visibility of signage is essential for ensuring safe navigation and effective traffic management along highways and urban roads.

13.1 Impact of Covered Signages

Visibility Impairment: Vegetation covering signage obstructs their visibility, making it difficult for drivers to identify important information such as speed limits, warnings, directions, and lane changes.

Navigation Challenges: Covered signage can lead to confusion and uncertainty among drivers, especially in unfamiliar areas or during adverse weather conditions when visibility is already reduced.

Safety Risks: Reduced visibility of signage increases the likelihood of missed turns, abrupt lane changes, and other unpredictable driving behaviors, potentially causing accidents and traffic congestion.

13.2 Importance of Clear Signage Visibility

Information Accessibility: Clear and visible signage provides essential information to drivers promptly, allowing them to make informed decisions and navigate safely.

Traffic Management: Well-maintained signage supports efficient traffic flow by guiding drivers through intersections, indicating lane changes, and alerting them to potential hazards ahead.

Compliance with Regulations: Maintaining clear signage visibility ensures compliance with traffic regulations and enhances road safety standards set by transportation authorities.

13.3 Mitigation Strategies

Vegetation Management: Regular trimming and pruning of vegetation around signage areas ensure clear visibility from a distance and at varying angles, minimising obstruction to drivers.

Signage Placement: Strategically placing signage in locations where vegetation growth is less likely to obstruct visibility can prevent future coverage issues.

Reflective Materials: Using reflective materials and coatings on signage enhances visibility during nighttime and adverse weather conditions, improving overall road safety.

13.4 Community Engagement and Maintenance

Public Awareness Campaigns: Educating local communities and property owners about

the importance of maintaining clear signage visibility encourages proactive vegetation management.

Collaboration with Authorities: Collaboration between transportation agencies, municipalities, and landscaping companies facilitates timely maintenance and ensures ongoing visibility of road signage.

Regular Inspections: Implementing routine inspections to identify and address signage visibility issues promptly minimises risks and enhances driver awareness on roadways.

Ensuring that road signage remains visible and accessible by managing vegetation effectively plays a crucial role in maintaining road safety and facilitating smooth traffic flow. By implementing proactive strategies and fostering community involvement, authorities can mitigate hazards associated with obscured signage and improve overall road navigation experiences.

14. Untreated Sudden Lane Drop/Narrow Road Section

Sudden lane drops and narrow road sections that are left untreated can pose severe safety hazards for drivers, leading to confusion, abrupt manoeuvres, and an increased risk of crashes. These issues are particularly critical in high-speed or high-traffic areas where drivers have less time to react. Addressing these hazards according is crucial for maintaining road safety and ensuring smooth traffic flow.

14.1 Impact of Untreated Sudden Lane Drop/Narrow Road Sections

Driver Confusion: Sudden lane drops and narrowing road sections without prior warning can confuse drivers, causing abrupt lane changes or sudden braking.

Increased Accident Risk: These abrupt changes in road geometry can lead to collisions, particularly in high-speed areas where drivers have less time to react.

Traffic Congestion: Sudden lane reductions can create bottlenecks, leading to traffic congestion and increased travel time.

14.2 Importance of Treatment

Safety Enhancement: Properly treating sudden lane drops and narrow road sections enhances road safety by providing drivers with adequate warnings and guidance, reducing the likelihood of accidents.

Regulatory Compliance: Adhering to the standards set by the Indian Roads Congress (IRC) ensures compliance with national regulations, promoting uniformity and safety across the road network.

Driver Confidence: Clearly marked and treated road sections instill confidence in drivers, allowing for smoother and safer driving experiences.

14.3 Recommended Treatments

Advance Warning Signs: According to IRC: 67-2022, advance warning signs should be placed at least 120 meters before the start of the lane drop or narrow section in rural areas, and at least 60 meters in urban areas. These signs alert drivers to upcoming changes in road conditions.

Lane Markings: As per IRC: 35-2015, clear and visible lane markings should be used to guide drivers through lane drops and narrow sections. Continuous lines should be used to

indicate no lane change, while broken lines can guide merging or diverging lanes.

Reflective Markings and Delineators: Utilizing retro-reflective road markings and delineators enhances visibility during nighttime and adverse weather conditions, as recommended by IRC: 79-2019.

Speed Reduction Measures: Implementing speed reduction measures, such as speed humps or rumble strips, before the lane drop or narrow section can help reduce vehicle speed, providing drivers with more time to react to the change.

14.4 Infrastructure Improvements

Widening Projects: Where feasible, road widening projects should be undertaken to eliminate narrow sections, providing consistent lane width and reducing the risk of accidents.

Transition Zones: Designing smooth transition zones, where the road gradually narrows or lanes merge, can help drivers adjust their speed and position more comfortably, as outlined in IRC: SP: 84-2014.

Signage and Road Furniture: Installing additional signage and road furniture, such as guardrails or bollards, can provide physical and visual cues to guide drivers safely through lane drops and narrow sections.

14.5 Maintenance and Monitoring

Regular Inspections: Conducting regular inspections of road conditions ensures that lane markings, signage, and other treatments remain visible and effective.

By adhering to these guidelines and implementing treatments according to Indian standards, road authorities can significantly reduce the risks associated with sudden lane drops and narrow road sections, enhancing overall road safety and efficiency.

14.6 Untreated narrow bridge section

It will function as a sudden lane drop, posing significant hazards to the road users and causing issues.

14.6.1 List of Issues

Traffic Congestion: Untreated narrow bridge sections often lead to traffic congestion due to restricted vehicle flow and limited passing opportunities, particularly during peak travel times.

Impact with Hard Structure: Drivers navigating untreated narrow bridge sections may be at risk of colliding with bridge barriers or structures, potentially causing vehicle damage or injuries.

Increased Risk of Collisions: The confined space and reduced visibility on untreated narrow bridges heighten the likelihood of side-swiping or rear-end collisions among vehicles.

Structural Integrity Concerns: Untreated narrow bridges may deteriorate faster under heavy traffic, necessitating frequent maintenance to ensure safety and structural stability.

Pedestrian and Cyclist Safety: Lack of dedicated lanes or space for pedestrians and

cyclists on untreated narrow bridges exposes them to increased risk from passing vehicles.

Sudden Braking/Reduction in Speed: Drivers often need to abruptly reduce speed or brake suddenly on untreated narrow bridges, disrupting traffic flow and potentially causing rear-end collisions.

14.6.2 Possible solution:

Lane Marking: Clear and visible lane markings on treated narrow bridges help guide drivers and prevent lane encroachment, enhancing traffic flow and safety.

Effective Traffic Channelization: Properly designed traffic patterns and barriers on treated narrow bridges ensure smooth vehicle movement and reduce the risk of collisions by directing traffic into designated lanes.

Speed Reduction Measures: Implemented speed limits and speed reduction measures such as speed bumps or rumble strips on treated narrow bridges encourage safe driving speeds, improving overall road safety.

Illumination and Road Delineators: Adequate lighting and reflective road delineators on treated narrow bridges enhance visibility during low-light conditions, aiding drivers in navigating safely.

Warning Signages: Strategically placed warning signs on treated narrow bridges alert drivers to upcoming hazards, such as sharp turns or narrow lanes, promoting caution and reducing accidents.

15. Damaged Pavement Sections

Damaged pavement sections pose significant risks to road users, compromising safety, vehicle performance, and overall road quality. Addressing these issues promptly and effectively according to Indian standards is crucial for ensuring smooth and safe transportation networks across urban and rural areas.

15.1 Impact of Damaged Pavement Sections

Safety Hazards: Potholes, cracks, and uneven surfaces in pavement sections increase the risk of crashes, especially for two-wheeler riders and cyclists.

Vehicle Damage: Rough pavement surfaces can cause mechanical damage to vehicles, including tire punctures, wheel alignment issues, and suspension damage.

Traffic Disruption: Damaged pavement sections contribute to traffic congestion as drivers manoeuvre to avoid hazards, slowing down overall traffic flow.

25.2 Importance of Repair

Enhanced Safety: Repairing damaged pavement sections improves road safety by providing a smoother surface for vehicles, reducing the likelihood of accidents caused by sudden manoeuvres or loss of control.

Road Quality: Maintaining pavement integrity ensures longevity and durability, preserving infrastructure investment and minimizing future repair costs.

User Experience: Smooth and well-maintained pavements enhance comfort and convenience for all road users, contributing to overall satisfaction and efficiency in transportation.

15.3 Recommended Repair Methods

Pothole Patching: According to IRC: 82-2015, potholes should be repaired using appropriate materials and techniques to ensure long-lasting durability and safety.

Crack Sealing: IRC: 82-2015 recommends crack sealing to prevent water infiltration and further pavement deterioration, extending the life of the road surface.

Overlay and Resurfacing: When pavement damage is extensive, overlay or resurfacing with suitable materials, as per IRC: 81-1997, restores pavement integrity and smoothness.

15.4 Infrastructure Improvements

Regular Maintenance: Implementing routine inspection and maintenance schedules ensures early detection of pavement issues and timely repairs.

Quality Materials: Using high-quality materials and adhering to IRC specifications during repairs ensures durability and long-term performance of repaired pavement sections.

Traffic Management: Proper traffic management during repair works minimizes disruption and ensures the safety of road users and construction personnel.

15.5 Community Engagement and Monitoring

Public Awareness: Educating the public about the importance of reporting pavement issues promotes community involvement in maintaining road quality.

Performance Monitoring: Utilizing performance monitoring techniques, such as pavement condition surveys and data analysis, helps assess the effectiveness of repairs and plan future maintenance.

15.6 Environmental Considerations

Sustainable Practices: Incorporating environmentally friendly practices in pavement repair, such as using recycled materials or sustainable construction methods, reduces ecological impact.

Water Management: Implementing drainage improvements alongside pavement repairs helps mitigate water runoff issues and prolongs pavement lifespan.

Vegetation Control: Managing vegetation around pavement areas prevents root damage and reduces the likelihood of future pavement cracking or heaving.

15.7 Technological Innovations

Advanced Pavement Materials: Exploring and adopting advanced pavement materials, such as polymer-modified asphalt or concrete, enhances durability and reduces maintenance needs.

Remote Sensing and Monitoring: Utilising remote sensing technologies and real-time monitoring systems enables early detection of pavement issues, improving response times and overall road network efficiency.

By integrating comprehensive approaches to pavement repair and maintenance, adhering to standards, and embracing technological advancements and community engagement, road authorities can effectively manage and improve the condition of damaged pavement sections, ensuring safer and more efficient transportation networks for all users.

16. Roadside Encroachment

Roadside encroachment is a pervasive issue that affects road safety, traffic management, and infrastructure integrity across urban and rural areas. Addressing these challenges comprehensively according to Indian standards is essential for maintaining clear and safe transportation corridors, ensuring smooth traffic flow, and enhancing the overall quality of road networks.

16.1 Impact of Roadside Encroachment

Safety Hazards: Unauthorized structures, parked vehicles, signage, or merchandise encroaching onto road shoulders can obstruct visibility, creating blind spots for drivers and pedestrians.

Traffic Congestion: Encroachments reduce effective road width, leading to bottlenecks and congestion, especially in urban areas with high vehicular and pedestrian traffic.

Infrastructure Damage: Encroachments can damage road surfaces, drainage systems, and utilities, necessitating frequent repairs and maintenance that strain public resources.

16.2 Importance of Addressing Encroachment

Enhanced Road Safety: Clearing roadside encroachments improves visibility and ensures safer passage for all road users, reducing the risk of accidents and collisions.

Preservation of Infrastructure: Maintaining clear roadside corridors protects road assets from damage and deterioration, extending their service life and reducing maintenance costs.

Regulatory Compliance: Adhering to guidelines set by the Indian Roads Congress (IRC) ensures uniformity and compliance with national standards, fostering efficient management of public spaces.

16.3 Recommended Strategies and Measures

Encroachment Removal: Implementing regular monitoring and enforcement to remove unauthorized structures, parked vehicles, and obstructions from road shoulders and right-of-way areas.

Designated Zones: Establishing designated parking areas away from road edges with proper signage and enforcement to discourage roadside parking and ensure smooth traffic flow.

Street Vending Regulations: Enforcing regulations for street vendors to ensure their activities do not encroach onto roadways, sidewalks, or pedestrian paths, maintaining accessibility and safety.

16.4 Infrastructure and Management Practices

Routine Inspections: Conducting regular inspections of roadside areas to identify and address encroachment issues promptly, ensuring compliance with safety and regulatory standards.

Public Awareness and Education: Engaging with local communities and stakeholders to raise awareness about the importance of maintaining clear roadside corridors and complying with regulations.

Collaboration with Authorities: Partnering with local authorities, municipalities, and law enforcement agencies to coordinate efforts in

enforcing encroachment regulations and managing public spaces effectively.

16.5 Monitoring and Evaluation

Performance Metrics: Establishing performance indicators and conducting periodic evaluations to assess the effectiveness of encroachment management strategies and initiatives.

Emergency Access and Response: Ensuring unobstructed roadside corridors to facilitate swift emergency vehicle access and response, enhancing public safety and disaster preparedness.

By implementing a comprehensive approach that includes proactive enforcement, community engagement, infrastructure management, and adherence to Indian standards, road authorities can effectively mitigate the impacts of roadside encroachment. This approach not only enhances road safety and traffic management but also promotes sustainable and efficient use of public spaces for the benefit of all road users and communities.

17. Vision Obstructions due to excess vegetation and Series of Trees

Vegetations are natural entities present near the roads or introduced as a part of landscaping activities. These acts as natural edging and as barriers for glare and vehicular noise.

The vegetation enhances the natural environment but can pose a threat to commuters since it blocks the visual connections between the road geometry and the road users. This vision obstruction can cause potential crashes.

17.1 Potential threats due to vegetation

(a) Vision obstruction of road geometry: Vision obstructions of the road features like curves, road intersections, minor access roads, pedestrians approaching the main carriageway to cross the road and changes in lane width on high-speed road sections create potential conflict zones.

(b) Vision obstruction of hard structures: Vegetation blocking hard structures like pillars, stone or rock mass, and parapet walls increases the scope of object impacts on the highway stretch.

(c) Potential Hard Structures: Tree trunks and branches in the shoulder or by the carriageway pose the threat of hard structure and plays one of the roles in Road Traffic Crash (RTC) fatalities.

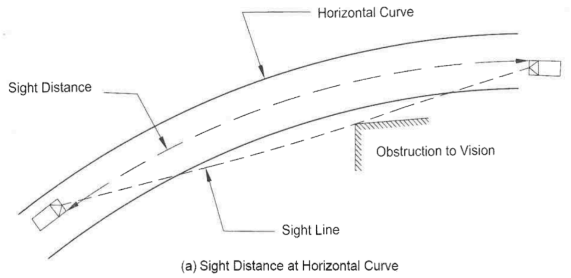
(d) Physiological impact: Branches tilted towards the carriage way creates a physiological impact on the driver's mind which ultimately results in sudden braking and steering.

17.2 Mitigation Strategies:

(a) Clear Sight Distance[20]: Plantations should adhere to guidelines for clear sight distance/vision based on the designated speed of the corridor.

(b) Height of the Plants: For roadside plantations (excluding the main carriageway and both paved and unpaved shoulders), plants should be selected so that their maximum height does not exceed 0.75 to 1.0 metres from the ground.

[20] Source: IRC 73:2023



(a) Sight Distance at Horizontal Curve

(c) Series of Trees: Reduce the number of trees by removing dead or infected ones. Trees in a series should be regularly trimmed, ensuring no plants or vines grow in the spaces between the trees or on any hard structures.

18..Absent safety during routine maintenance works or construction zone

Inadequate treatment of construction zones poses significant road safety risks. Without proper signage, barriers, and traffic control measures, drivers may be unaware of the construction area, leading to sudden lane changes and potential collisions. Additionally, the lack of clear guidance and safe pathways can endanger both construction workers and road users, increasing the likelihood of accidents and injuries.

18.1 Impact of Inadequate treatment of construction zone

Increased Risk of Accidents: Poorly marked or unmarked construction zones can lead to sudden braking or lane changes, causing collisions.

Driver Confusion and Traffic Congestion: Lack of clear signage and lane markings can confuse drivers, resulting in erratic driving behaviour and potential accidents. Ineffective traffic management and unclear detours can create bottlenecks, leading to severe traffic congestion and delays.

Emergency Response Delays: Traffic congestion and unclear routes can delay emergency vehicles, affecting their ability to respond quickly to incidents.

Vehicle Damage: Uneven road surfaces, potholes, and debris in inadequately managed construction zones can cause significant damage to vehicles.

Danger to On-Site Workers and Other Road Users: Inadequate treatment of construction zones places on-site workers at high risk of being struck by vehicles due to insufficient barriers and signage. This also endangers other road users as they navigate unpredictable traffic patterns and potential hazards, increasing the likelihood of accidents.

18.2 Recommended Measures[21]

Advance Warning Signals: Install advance warning signs to alert drivers of upcoming construction zones, allowing them to slow down and prepare for changes in traffic patterns.

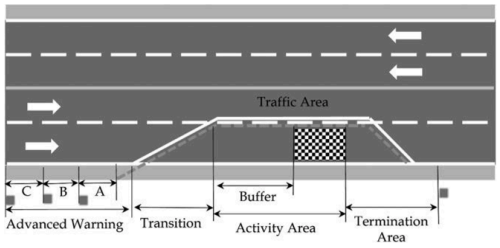
Blinkers, Illumination, and Road Delineators: Use blinkers, adequate lighting, and reflective road delineators to improve visibility and guide drivers safely through the construction area, especially at night.

Traffic Channelization: Implement effective traffic channelization with cones, barriers, and lane markers to direct vehicles safely through or around the construction zone,

[21] Source: IRC SP 55:2014

minimising confusion and the risk of accidents.

Cleaning of Sand and Loose Gravels: Regularly clean the construction site to remove sand, loose gravel, and debris that could cause vehicle damage or loss of control, ensuring a safer driving surface.



Avoid Sharp Corners: Design construction zone layouts to avoid sharp corners, which can be difficult to navigate and increase the risk of collisions, particularly for larger vehicles.

Alternative route if Possible: Provide and clearly mark alternative routes to divert traffic away from the construction zone, reducing congestion and improving safety for both road users and construction workers.

19 Inadequate safety treatment at bus stops

Bus stops are critical points in transportation networks, serving as the primary locations for passengers to board and alight from public transit vehicles. Bus stops are prime locations for pedestrian crashes on highways due to the high number of pedestrian movement (crossing and walking), particularly considering the elderly population. However, inadequate safety measures at bus stops pose significant risks to both passengers and drivers, leading to crash, injuries, and fatalities.

19..1 Key Issues at the bus stops

a. Absent signage or Poor Visibility of Signage
b. Insufficient Space and Shelters
c. Lack of Pedestrian Infrastructure
d. Inadequate Road Markings and Speed Control.
e. Poorly so Designed Bus Stop Locations and buffer space

19..2 Solution for the bus stop.[22]

a. General Principles of Location

> Bus stops should be located away from bridges, important structures, and embankments over four metres high, avoiding horizontal and summit vertical curves. Additionally, good visibility corresponding to a safe stopping sight distance must be ensured.

> Bus stops should be placed at a distance of 60 metres form the minor intersection and major intersection.

> For the hilly areas choose the location which is flat for both the sides and sight distance should not be less than 50 metres. It's more preferable to have bus stops where it is possible to have road widening accommodating bus laybys, passenger shelters, etc.

b. Pedestrian volume data

For the straight section of the road, pedestrian volume data should be conducted

[22] **Source:** IRC : 80 -2022

to choose the optimised location for the setup of the bus stop to reduce the multiple boarding and alighting points.

c. Layout and Design[23]

While designing the bus stops below points should be consider:

- ➢ Number of buses stopping at a time.
- ➢ Period of halt (how long buses stay)
- ➢ Traffic volume on the road
- ➢ Number of passengers getting off at the bus stop
- ➢ Ideally, separate laybys on both sides of the road for each travel direction.
- ➢ Length of the laybys should be 15 metres.
- ➢ Increased in multiples of 15 metres if multiple buses stop simultaneously.
- ➢ For the hilly areas bus stops on opposite sides should be staggered (offset) to avoid congestion.

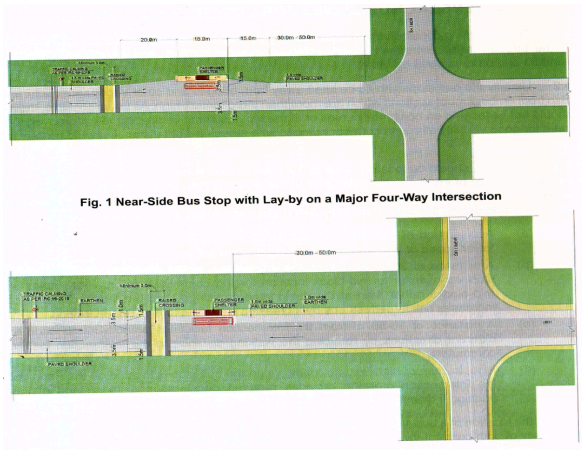
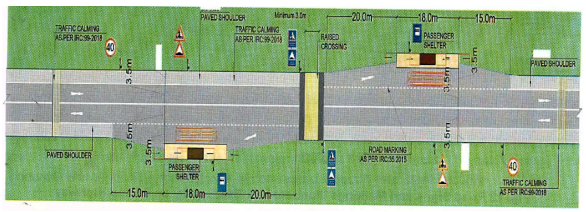
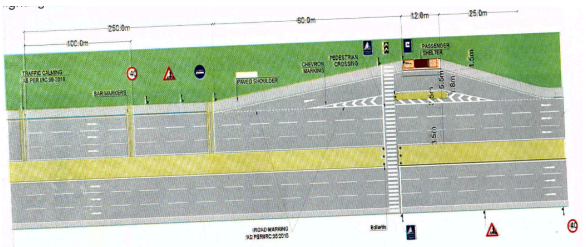
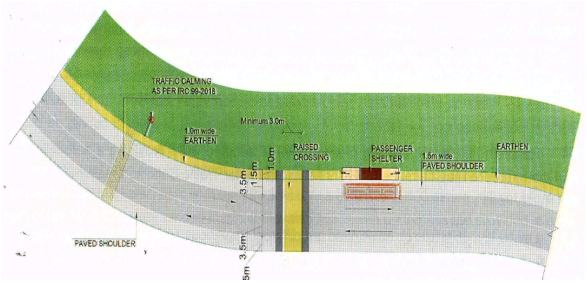
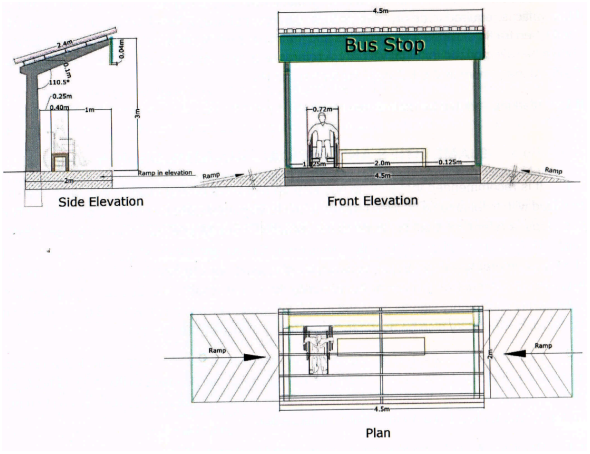


Fig. 1 Near-Side Bus Stop with Lay-by on a Major Four-Way Intersection









[23] Source: IRC 80 - 2022