IRDES

State of the art report on existing treatments for the design of forgiving roadsides

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Executive summary

Analyses of fatal road accidents in the European Union show that 45 percent are single vehicle accidents. These accidents are primarily classified as run-off-road accidents, where the vehicle leaves the road and enters the roadside. A roadside is called unforgiving, if hazardous objects such as trees are placed in an inappropriate distance to the road so that the risk of severe accidents is increased.

The European road directors declared the implementation of forgiving roadsides as one of the most promising short-term measures to increase road safety. The purpose of this concept is to avoid crashes of errant vehicles or to minimize crash consequences.

The goal of work package one of the IRDES project is to collect and harmonize common standards and guidelines for roadside treatments. Initially, this deliverable introduces typical roadside hazards, which are the basis for appropriate counter-measures. The main part of this report comprises results and findings of relevant literature, guidelines and standards dealing with roadside treatments.

Summarizing the literature study, three categories of treatments are proposed:

1. The removing or relocation of potentially dangerous roadside objects
2. The modification of roadside objects or design
3. The shielding of roadside objects

These three categories determine the main structure of the report. The first category mainly comprises recommendations for so-called safety zones. These are obstacle-free areas beyond the travel lane in order to avoid collisions. Additionally, these zones assist drivers to perform easy recovery manoeuvres. Especially for road planning, an appropriate safety zone should be considered.

If hazardous obstacles cannot be removed or relocated, they need to be modified. Crashworthy structures or breakaway devices are common examples for modifications. Moreover, the design of slopes and ditches are relevant factors for a safe road.

In many cases, removing or modifying hazardous objects is not possible or economically advisable. Isolating or shielding the drivers from the respective objects helps to minimize the severity of a crash. Safety barriers and attenuators at bridge abutments are good examples for this kind of treatment.

The output of this deliverable is a harmonized collection of state-of-the-art treatments to make roadsides forgiving. In further work packages of IRDES, the effectiveness of the treatments will be assessed by several methods. The final outcome of the IRDES project is a practical guideline for forgiving roadside design in Europe, referring to the results and findings of this report.

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Abbreviations

Abbreviation	**Definition**
AADT	Annual average daily traffic
AASHTO	American Association of State and Highway Transportation Officials
ADT	Average Daily Traffic
CEDR	Conference of European Directors of Roads or Conférence Européenne des Directeurs des Routes
ERA-NET	European Research Area Network
IRDES	Improving Roadside Design to Forgive Human Errors
NCHRP	National Cooperative Highway Research Programme
PTW	Powered Two-Wheeler
RISER	Roadside Infrastructure for Safer European Roads
ROR	Run-off-road
RVS	Richtlinien und Vorschriften für das Straßenwesen
SVA	Single vehicle accident
TG	Technical Group
TRB	Transportation Research Board

1 Introduction

IRDES (Improving Roadside Design to Forgive Human Errors) is a research project of the cross-border funded joint research programme “ENR SRO1 – Safety at the Heart of Road Design”, which is a trans-national joint research programme that was initiated by “ERA-NET ROAD – Coordination and Implementation of Road Research in Europe” (ENR), a Coordination Action in the 6th Framework Programme of the EC. The funding partners of this cross-border funded Joint Research Programme are the National Road Administrations (NRA) of Austria, Belgium, Finland, Hungary, Germany, Ireland, Netherlands, Norway, Slovenia, Sweden and United Kingdom.

1.1 Motivation and goals

Each year 43,000 persons are fatally injured in Europe due to road accidents. The RISER project has shown that even though 10 percent of all accidents are single vehicle accidents (typically run-off-road (ROR) accidents) the rate of these events increases to 45 percent when only fatal accidents are considered (see [A.2]). One of the key issues of this high ROR fatality rate is to be found in the design of the roadsides that are often “unforgiving”. CEDR has identified the design of forgiving roads as one of the top priorities within the Strategic Work Plan. For this reason, a specific Team dealing with Forgiving Roadsides has been established within the Technical Group (TG) on Road Safety of CEDR.

A number of different studies have been conducted in recent years to design roadsides to forgive human errors, but there is still a need for:

- A practical and uniform guideline that allows the road designer to improve the forgivingness of the roadside
- A practical tool for assessing (in a quantitative manner) the effectiveness of applying a given roadside treatment

The aim of the IRDES project is to produce these two outputs with specific reference to a well identified set of roadside features. The goals of this report are to summarize state-of-the-art treatments to make roadsides forgiving, as well as to harmonize currently applied standards and guidelines.

A non-goal of this deliverable is to assess the effectiveness of the presented treatments. This topic is part of another work package of IRDES, where tools and methods to evaluate treatments are analysed.

1.2 Methodology

The project team of IRDES created the following work plan:

WP0: Coordination and Management

WP1: Collection and harmonization of studies and standards on roadside design

WP2: Assessment of Roadside Intervention Effectiveness

WP3: Production of a Roadside Design Guide

WP4: Pilot Project

WP5: Organization of Workshops and Round Tables

This deliverable presents the results and findings of Work Package 1, which include a collection of relevant literature, position papers, guidelines and project summaries regarding roadside design. The goal is to harmonise this literature under consideration of existing national and international standards. Therefore, all project partners provided the authors of this deliverable with information gathered about their national standards, as well as with relevant scientific documents. An expert workshop has not been carried out in the scope of this work package.

This report aims to harmonize common approaches for roadside treatments that are carried out throughout the world. By doing so, the basis is provided to develop a practical and uniform guideline for effective roadside treatments in WP3 of the IRDES project. After reviewing relevant literature, the following categories of treatments to improve roadside safety were worked out:

1. Removing and relocating obstacles
2. Modifying roadside elements
3. Shielding obstacles

These three categories are based on the works of Waugh [A.1] and the U.S. Department of Transportation [B.17] and define the structure of this deliverable (see Chapter 3.1 to Chapter 3.3). The idea of a fourth category called “Delineating road obstacles” is suggested in the Roadside Design Guide of AASHTO [B.1] and mentioned in [B.17]. It means that the driver’s awareness of hazards should be increased when other treatments are not possible.

Existing roadsides can be improved and new roadsides can be safely constructed[1] by following a number of prioritised measures:

First, fixed objects that may be hazardous should be eliminated from the roadside. This provides a safety zone for the drivers to regain control over their vehicle, return to the travel lane or stop. Safety zones (sometimes called clear zones) are described in Chapter 3.1.1. Especially in the planning phase of a new road, safety zones should be considered. If fixed obstacles cannot be removed completely, it should be tried to relocate them. The further away an obstacle is located from the travel lane, the smaller the chance to hit it.

The second treatment category should be considered if the obstacle can neither be removed nor relocated. In this case, the structures of the objects should be modified in order to make it breakaway or energy absorbing, or even traversable like culvert ends.

In some cases, hazardous roadsides cannot be improved by applying the previous treatments. Isolating or shielding the drivers from the respective objects helps to minimize the severity of a crash. Safety barriers and bridge abutments are good examples for this kind of treatment. When no other measure can be made to work, hazardous roadside objects should be delineated and lane markings should be improved in order to limit the likelihood of runoff road accidents and obstacle hits.

These three categories can be seen as top-level treatment types that will be subdivided into several single treatments. They are explained in subchapters, containing references to existing standards, guidelines or research papers.

1.3 Definition of roadside

According to the RISER project [A.2], a roadside is defined as the area beyond the edge line of the carriageway. There are different views in literature on which road elements are part of the roadside or not. In this report, the median is considered as roadside, since it defines the area between a divided roadway. Therefore, all elements located on the median are considered as roadside elements as well. Figure 1 depicts a roadway cross section (cut and embankment section) including some roadside elements. In this specific figure, the roadside can be seen as the area beyond the traffic lanes (or carriageway). The shoulders are thus part of the roadside, since the lane markings define the boundaries. The slopes, the clear zones (also called safety zones) or the tree are examples for roadside features that will be described in the following chapters in detail.

[1] These improvements for new roadside should also be applied to existing roads, whenever possible.

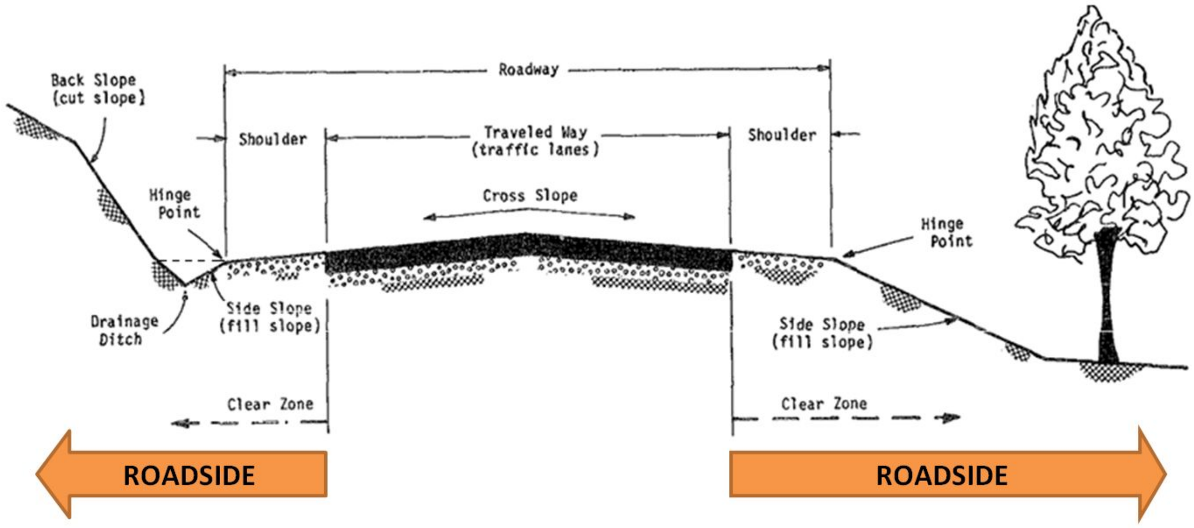

Figure 1: Roadway cross section with examples for roadsides with clear zones [B.17]

1.4 Forgiving vs. self-explaining

Forgiving and self-explaining roads are two different concepts of road design, which aim at reducing the number of accidents on the whole road network. The project IRDES and therefore this report only deals with forgiving roadsides. However, the term “self-explaining” needs to be defined in order to differentiate it from the term “forgiving”.

According to [A.5], self-explaining roads are based on the idea that appropriate speed or driving behaviour can be induced by the road layout itself. They therefore reduce the need for speed limits or warning signs. It is generally known that multiple road signs in complex traffic situations can lead to an information overload and an increasing risk of driving errors. Herrstedt [A.6] writes that a safe infrastructure depends on a road-user-adapted design of different road elements such as markings, signs, geometry, equipment, lighting, road surface, management of traffic and speed, traffic laws etc. The idea behind self-explaining roads is to design the road according to an optimal combination of these road elements.

In short, it can be said that self-explaining roads aim at preventing driving errors, while forgiving roads minimize their consequences. The first priority of forgiving roadsides is to reduce the consequences of an accident caused by driving errors, vehicle malfunctions or bad roadway conditions. It must be focused on treatments to bring errant vehicles back onto the lane to reduce injury or fatal run-off-accidents. If the vehicle still hits a road element, the second priority is to reduce the severity of the crash. In other words, the roadside should forgive the driver for their error by reducing the severity of run-off-road accidents.

2 Roadside hazards

The forgiving roadside concept emerged in the mid 1960s to account for the fact that vehicles can run off the roadway. The reasons for vehicles to leave the roadway have been grouped into [B.1] the following:

- Driver operation such as inattention, fatigue, influence of alcohol or drugs, evasion manoeuvres, excessive speed etc.
- Roadway conditions such as poor alignment, poor visibility, reduced pavement friction, inadequate drainage, substandard signing, marking or delineation etc.
- Vehicle malfunctions such as steering and braking failures, tire blowouts etc.

The main factors that affect the severity of a run-off-road accident are the layout and type of objects within the roadside. A main objective of designing forgiving roadsides is to provide clear zones, which is not always possible. Some roadsides have potential hazards for the drivers close to the carriageway. Often the placement of certain objects such as lighting poles, traffic signs or bridge barriers cannot be avoided. Other objects such as embankments, slopes or ditches affect roadside safety and should be treated in an effective manner. As stated in [B.17], a roadside object is considered hazardous when one or more of the following events occur:

- The vehicle is abruptly stopped.
- The passenger compartment is penetrated by some external object.
- The vehicle becomes unstable due to roadside elements.

In [B.2], a roadside hazard is any non-breakaway or non-traversable roadside feature that is greater than 100 mm in diameter or thickness. The RISER project showed that trees are the most dangerous roadside objects. Around 17 percent of all tree accidents recorded were fatal [A.2]. In the case studies of this investigation, where speed data were known, all fatal accidents involved impact speeds of 70 km/h or more. Structures such as signs, concrete walls, fences etc. are hit in 11 percent of all fatal single vehicle accidents (SVA). According to the RISER accident analysis, safety barriers appear to be the object most impacted in SVA. However, safety barrier SVA generally resulted in minor injuries. It should be noted anyhow that safety barriers themselves can pose a hazard if not properly designed and installed.

The study in [C.1] is based on the U.S. Department of Transportation's Fatality Analysis Reporting System (FARS) and shows the results of an analysis of fatal accidents caused by striking fixed objects. In total, 8,623 fatalities have been analysed. Figure 2 shows the distribution of fixed object crash deaths in 2008. It clearly depicts the high percentage of tree accident deaths (48 percent). Utility poles and traffic barriers were the next most frequent objects struck.

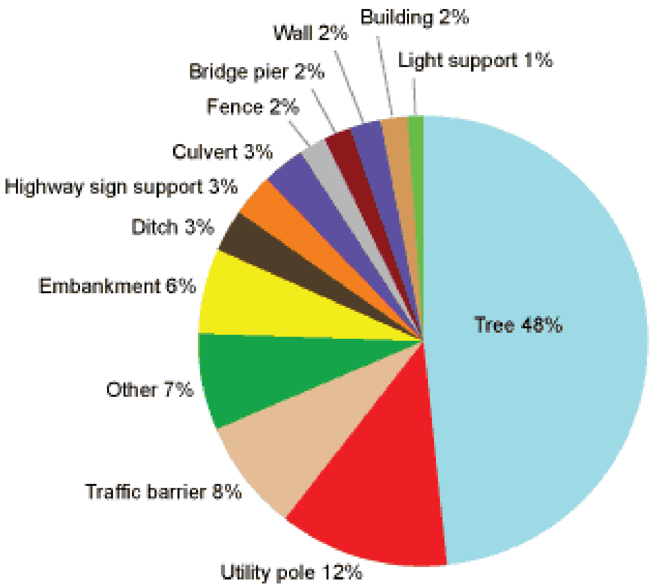

Figure 2: Percent distribution of fixed object crash deaths, based on 8,623 fatalities, 2008 [C.1]

In many crashes, the vehicle hits more than one roadside object. A study published by the Roads and Traffic Authority of New South Wales in Australia [A.7] examined the specific types of roadside objects that were hit by vehicles in second impacts. The analysis only contained fatal accidents and indicates again that trees are the most frequently struck roadside objects, followed by utility poles and embankments. Trees and utility poles have the highest percentage of objects hit in first as well as second impact (see Figure 3). An interesting result of the study is the fact that water bodies only contribute in secondary object hit fatalities.

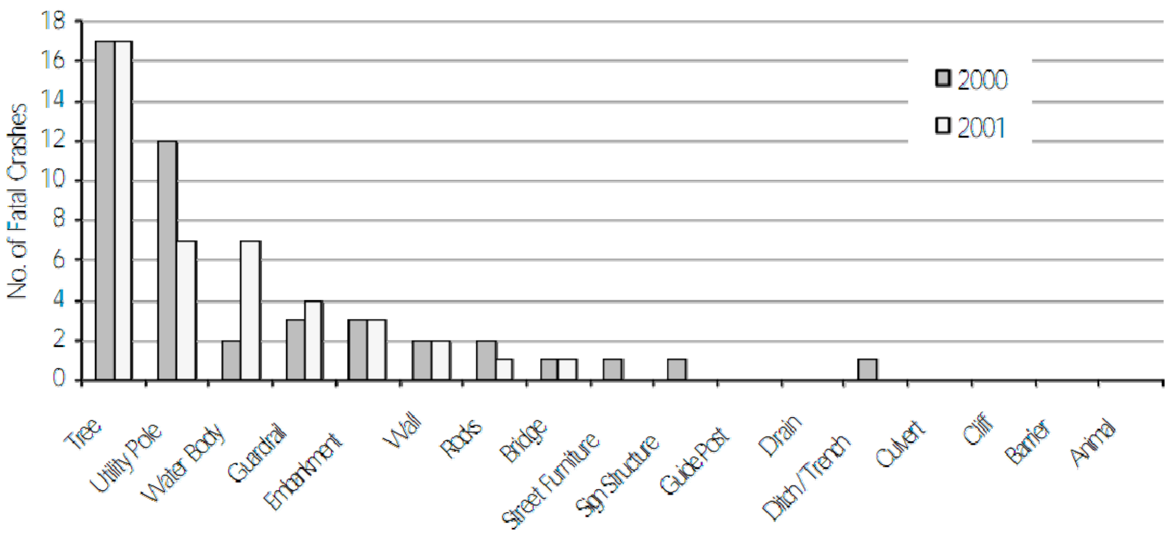

Figure 3: Roadside objects hit in second impact, based on 1,029 fatal accidents, NSW 2000 & 2001 [A.7]

This chapter deals with roadside hazards and gives an overview about a high number of exemplary objects. Treatments to improve hazardous roadside elements are presented in Chapter 3.1 to Chapter 3.3. The works in [B.17] and [A.2] present similar categorisations of hazardous obstacles. In this report, they are harmonised as follows:

1. Single fixed obstacles
2. Continuous obstacles
3. Dynamic roadside hazards

2.1 Single fixed obstacles

According to several studies, single or point objects make up the highest number of potential hazards along the roadside. According to [B.5], point hazards are defined as permanent installations of limited length. They can be natural or artificial, human-made structures made of different materials. Of course, large rigid structures such as bridge abutments cause the most severe accidents, since they do not provide sufficient energy absorbance. On the following pages, different examples of single obstacles as well as their degree of hazardousness are explained.

2.1.1 Trees and other vegetation

Accident analyses in [A.7] and [C.1] proved that tree crashes claim a high number of fatally injured victims. Compared to other roadside obstacles, trees or other rigid vegetations seem to be most hazardous. According to the RISER project, trees become particularly dangerous when the diameter exceeds 20 cm (see [A.2]) – in France it is 10 cm. The impact speed is considered dangerous if higher than 40 km/h. According to a study in [A.8], the injury severity for tree collisions is much higher than in all accidents recorded (see Figure 4).

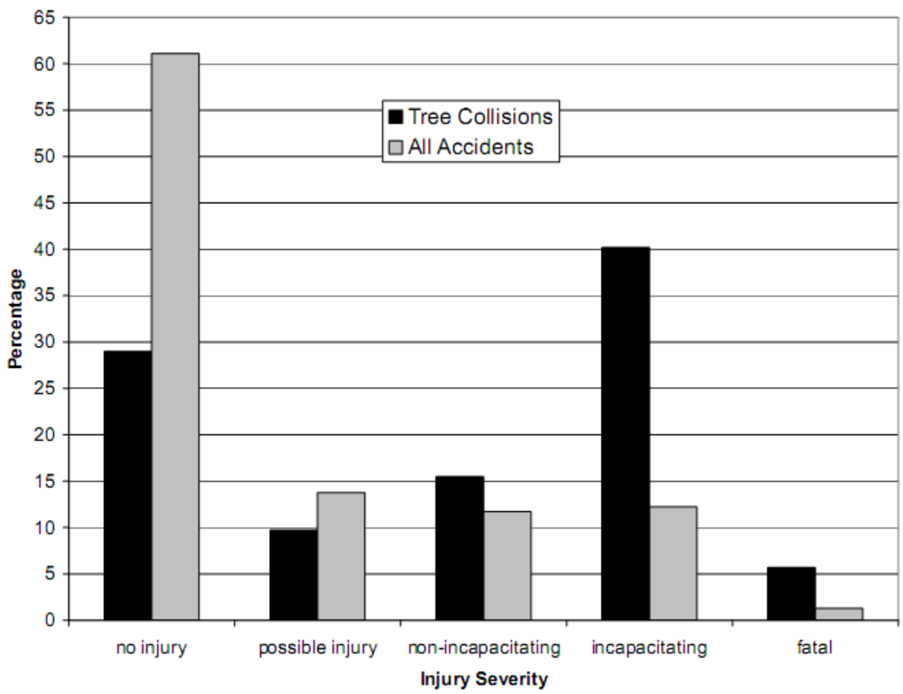

Figure 4: Relative frequency of injury severity for tree collisions and all accidents (in percent), based on 1,830 tree accidents [A.8]

A guide from the NCHRP [B.3] contains an interesting analysis of the relation between the average distance of trees to the travel lane and tree accidents. It shows that shorter distances result in more accidents. The example pictures in Figure 5 show trees that are located too close to the road without delineation or shielding. In the right picture, the tree was the second impacted object, after the vehicle hit the kerb.

Figure 5: Examples for hazardous trees located on the roadside (Source: [B.6], [C.6])

However, one should also consider a tree as an aesthetic roadside design element, as Bratton and Wolf did in [A.8]. Simply removing trees can be an emotional community issue. There are research gaps on how trees can be effectively incorporated into a safe roadside design that promotes community values and environmental amenities. Guidelines for a safe and aesthetic design of urban roadside treatments have been worked out in [B.4].

2.1.2 Utility poles

Utility poles typically carry power or telephone overhead cables. The poles are often made of rigid wood or concrete and can therefore be called “unforgiving”, since the energy absorbance ability is minimal. Two examples for hazardous utility poles located on the roadside are depicted in Figure 6. In both pictures, the poles are located within one meter of the road and are not shielded.

Figure 6: Two examples for hazardous utility poles (Source: [C.4])

Figure 2 shows that utility poles are the second most hazardous roadside obstacles regarding fatal accidents. One primary finding of a study by Mak and Mason [A.9] was that pole accidents are mostly urban problems with approximately 37 pole accidents per 100 miles of highway (~161 km) as compared to 5.2 for rural roads. They also found that pole accidents in rural areas have higher impact severities than urban pole accidents. Of course, the impact severity depends on the driving speed, which is generally higher on rural roads.

2.1.3 Sign and lighting posts and supports

Other than utility poles, the structures described here carry lights or traffic and warning signs. Mostly, they must be located close to the roadway and cannot be removed or relocated. They are hazardous if they are non-breakaway during impacts. The results in [C.1] show that sign and light supports cover four percent of the fixed object crash fatalities. The literature regarding in-depth analyses of crashes with pole facilities is limited.

In the RISER project, guidelines throughout Europe have been collected which define a minimum diameter of different types of posts and supports beyond which they are no longer considered safe. Further information can be found in [A.3]. Figure 7 shows two examples of hazardous poles on the roadside.

Figure 7: Examples for hazardous sign poles (Source: [A.3])

2.1.4 Abutments and tunnel entrances

Abutments, overpasses, bridge piers and walls at tunnel entrances are mostly made of rigid concrete and are considered extremely hazardous. According to RISER [A.3], such objects are dangerous, if the diameter of a pier is greater than 1 metre, if they are too close to the roadway or if they are unshielded. Often, the entrance to a tunnel is constructed in a way that does not allow a vehicle to slide along the structure. However, walls and bridge piers have a relatively small percentage of crash fatalities compared to other fixed objects (see Figure 2). Examples for a hazardous bridge abutment as well as an overpass are depicted in Figure 8.

Figure 8: Examples for a hazardous bridge abutment (left) and overpass (right) (Source: [A.2])

2.1.5 Safety barrier terminals and transitions

Safety barriers are forgiving roadside treatments to shield hazardous obstacles and/or to prevent vehicles from running off the roadway. However, the ends or transitions between two different types of rails can be hazardous roadside objects. Safety barrier ends are considered hazardous when the termination is not properly anchored or ramped down in the ground, or when it does not flare away from the carriageway [A.3]. The RISER database contains 41 accidents where barriers were the only obstacles involved. In 14 cases (i.e. 34.1 percent), the termination of the barrier was hit. Crashes with “unforgiving” safety barrier ends often result in a penetration of the passenger compartment.

The most common transition section occurs between bridge rail ends and approach barriers. In these cases in particular, the transitions may cause high decelerations and are therefore “unforgiving”. Figure 9 depicts two examples for dangerous safety barrier terminations. In the right picture, a transition between bridge rail and roadway guardrail is missing. Both ends have no proper end treatment.

Figure 9: Examples for hazardous safety barrier terminations

2.1.6 Rocks and boulders

Single rocks and boulders are dangerous obstacles when located too close to the roadway. Exposed outcrops mainly occur on roads constructed in a rocky environment, where the provision of a safety zone is expensive. A further hazard resulting from rock cuts on the roadside are fragments that can fall down from steep slopes onto the roadway. See Figure 10 for examples of such roadside hazards.

Figure 10: Examples for hazardous boulders (left) and rocks (right) on the roadside (Source: [A.2] and [A.3])

2.1.7 Drainage features

In case a vehicle runs off the road, drainage features like culverts or culvert ends are hazardous roadside obstacles. They are commonly used to channel a water course and are made of concrete, steel or plastic. According to [C.1], three percent of all fixed object crash deaths are caused by culverts. The examples in Figure 11 depict hazardous drainage structures. As seen in the left picture, these features are often made of rigid material, which cannot absorb the impact energy.

Figure 11: Examples for hazardous drainage features (Source: [A.2])

2.1.8 Other single fixed obstacles

Besides the obstacles mentioned above, other roadside objects may be hazardous for drivers. Single rigid structures like masonry road markings, hydrants, unshielded houses, artwork, etc. are common roadside features that must be treated in an effective manner. In the last decade, many roundabouts were subject to an artistic redesign to let the middle appear more attractive. Some of these artworks are extremely hazardous due to "unforgiving" construction and protruding parts. Especially motorcyclists can be seriously injured or killed when hitting such an artwork.

2.2 Continuous hazards

Continuous hazards are distributed objects that are of considerable length, making it unpractical to remove or relocate them. On the following pages, several examples of continuous hazards and their impact on roadside safety are presented.

2.2.1 Embankments and slopes

An embankment is a man-made ridge of earth or stone that carries a road or railway. The term comprises all kinds of sloping roadsides including cut and fill slopes (see Figure 12). A cut slope is the face of an excavated bank required to lower the natural ground line to the desired road profile. In contrast to that, a fill slope is the face of an embankment required to raise the desired road profile above the natural ground line[2]. How hazardous a slope is depends on its height or depth, its steepness and distance to the roadway. A detailed analysis of standards in different countries defining the thresholds for those parameters has been performed in the RISER project [A.3].

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[2] Definitions taken from the Ministry of Forests of Government of British Columbia

Figure 12: Examples for hazardous cut (left) and fill slopes (right) (Source: [A.2])

According to [C.1], embankments are hit in 6 percent of all fixed object crash deaths. The risk of a vehicle rollover is high when hitting an embankment, especially when it is a steep slope. The study also showed that nearly a third of all fatal embankment accidents are caused by rollover. This is the highest percentage of all objects included in the analysis.

2.2.2 Ditches

Ditches are defined as drainage features created to channel water, which mostly run parallel to the roadway. They are formed by the sideslope and backslope planes. Roadside designers must ensure that ditches are wide enough to provide adequate drainage and snow storage capacity. According to [B.2], a ditch deeper than 1 metre and with a sideslope steeper than 4:1 is considered hazardous and should be treated in an effective manner.

Figure 13: Examples for hazardous roadside ditches (Source: [B.8])

The graphic in Figure 2 shows that 3 percent of all fixed object crash fatalities are caused by run-offs in ditches. The literature on injury severity of ditch accidents is limited.

2.2.3 Road restraint systems

After trees and utility poles, road restraint systems (e.g. steel safety barriers, cable barriers, etc.) are the third most dangerous roadside obstacles [C.1]. Although mostly barrier terminations are hit, the rails themselves can be considered roadside hazards as well. The goals of a barrier are to prevent a vehicle from running off the road, as well as to protect vulnerable road users from traffic. Median barriers are commonly used to separate traffic in different directions and with high differential speeds.

Safety barriers should be constructed in a way to smoothly redirect impacting vehicles at a low departure angle [B.2]. However, accident studies have shown that redirected vehicles often interact with other vehicles, which results in severe accidents. Furthermore, some barriers are made of rigid or semi-rigid material to prevent run-offs at bridges or other dangerous roadsides. Some countries consider cable barriers as a hazardous roadside obstacle, especially from motorcyclists. Much research has been done in this area and there is little or no evidence that cable barriers / wire rope safety barriers are any more dangerous to motorcyclists than the normal metal Armco barriers-it is the poles that hold up the wire rope safety barrier and the Armco barrier which are the problem for motorcyclists. When a motorcyclist falls off their bike they are usually sent sliding along the road and the poles are their main concern. On the contrary, wire rope safety barrier is a lot more forgiving than either concrete barrier or metal Armco barriers - it will deflect and absorb the energy of the impact, while still containing the vehicle. As such it should not be considered any more of a hazard than any other safety barriers (see Figure 14).

Figure 14: Examples of collisions with safety barriers (Source: [A.10], [C.2])

2.2.4 Kerbs

In many urban environments, roadway shoulders are not practicable as a roadside treatment. Instead, kerbs are commonly used to prevent run-off-accidents. A kerb is typically the edge between a sidewalk and a roadway and consists of concrete, asphalt or a line of kerbstones. One purpose is to prevent motorists from driving onto the roadside, while the other purpose is to ensure an efficient drainage of the roadway. It should be noted that kerbs – like road restraint systems – are a treatment to improve roadside safety, but can simultaneously prove a hazard for motorists. A summary of studied safety aspects of kerbs in [B.4] includes the finding that kerbs do not have the ability to redirect vehicles upon impact. The most significant factor influencing a vehicle's trajectory is kerb height. Improper kerb design may lead to an impact with a second obstacle such as other vehicles or can cause vaulting of the vehicle.

2.2.5 Permanent water bodies

The term permanent water body describes rivers, lakes, canals or small ponds that are located on the roadside. When a vehicle enters the water body, the main hazard, which is the risk of drowning, arises.

2.2.6 Other continuous obstacles

During the creation of this report, a discussion arose whether forests should be included as continuous obstacles or not. The RISER guidelines distinguish between trees and a line of trees, since the treatments to improve them may differ. A whole line of trees, often planted for aesthetic reasons, is not as practical to remove or relocate as a single tree. Thus, they must be shielded using safety barriers.

Other distributed hazards could be unshielded pipelines or rigid structures like continuous walls. Rock outcrops may be considered continuous as well.

2.3 Dynamic roadside hazards

In [B.4], the term dynamic roadside features can be found, which include

- bicycle facilities,
- pedestrian facilities and
- parking.

In contrast to the hazards presented in Chapter 2.1 and 2.2, dynamic hazards are not fixed but moving. Dynamic roadside features are more prevalent in urban environments, which are generally more complex than rural roadsides. The literature regarding the relationship between dynamic roadside elements and roadside safety is limited. On the one hand, bicycle lanes or sidewalks provide an additional clear zone for drivers. On the other hand, bicycle hardware such as racks may be potential hazards for drivers. However, the risk concerns the pedestrians using the sidewalk rather than the drivers of vehicles. This leads to a different approach of roadside treatments, since the persons moving on the roadside must be protected. A study of the FHWA [A.10] determined that 11 percent of all pedestrian-vehicle-crashes recorded occurred at roadside locations such as sidewalks or parking lots.

In many urban environments, on-street parking is necessary and requires approximately 2.4 metres from the roadside. This results in a reduction of the travel lane width, as well as limited possibilities for clear zones. The risk of accidents caused by vehicles attempting to pull in or out of a parking space may rise, and sight distances are shortened. There is a need for treatments to ensure proper sight distances and safe separation of the travel lane and parking lots.

3 Treatments to make roadsides forgiving

In the previous chapter, a high number of potential hazards were described which affect roadside safety. This chapter deals with treatments for those hazards, considering three types of strategies to improve roadside safety:

1. Removing and relocating obstacles (see Chapter 3.1)
2. Modifying roadside elements (see Chapter 3.2)
3. Shielding obstacles (see Chapter 3.3)

In literature, delineation is often mentioned as treatment if all of the three measures above are unfeasible. Delineating can help a driver to avoid hitting roadside hazards. However, this measure is not included as a separate chapter, because it belongs to the strategies for self-explaining and not for forgiving roads.

Based on the proposed four steps for the treatment of roadside hazards written in [B.5], the following procedure was worked out for this report:

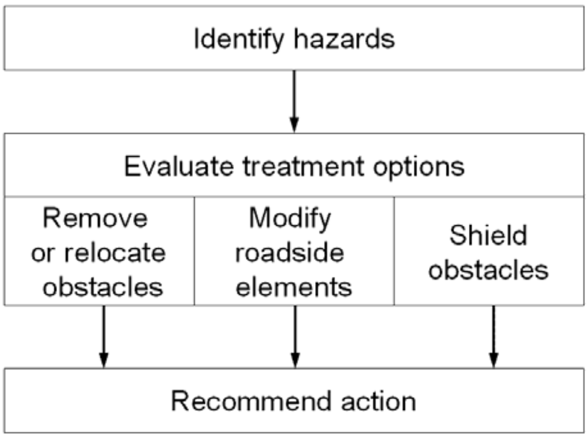


Figure 15: Procedure for forgiving roadside treatments

The three steps in Figure 15 can be applied either on existing roads or in the planning phase for new roads. Potential hazards must also be considered during planning, and the treatment may primarily be to provide a safety zone (often called clear zone) on the roadside. On existing roads, the identification of hazards can be established by road safety inspections or using accident histories. Moreover, hazards are identified by considering traffic volumes and speeds, road geometry, surface properties and the expected severity of crashes.

Another approach presented in [B.2] includes an additional step before the hazard identification: Determine desirable clear zone. Based on data such as design speed, slope information, curvature, topography or non-removable road furniture, the clear zone requirements are identified. The desirable clear zone width is the basis for the removing or relocation of obstacles. In this report, the step to determine safety zone requirements is included in the first category of treatments and will be explained in Chapter 3.1.1.

Several treatment options, which are the main concern of this report, are typically evaluated in a quantitative and qualitative assessment procedure. The assessment of treatments as well as their effectiveness will be dealt with in work package 2 of the IRDES project and are not described in this deliverable. The evaluation phase may result in a number of options, from which a treatment can be chosen. The outcome is one or more recommended actions, based on a prioritisation of the treatments.

3.1 *Removing and relocating obstacles*

3.1.1 The safety zone concept

The most obvious roadside improvement can be accomplished by providing a so-called safety zone, i.e. providing an obstacle-free area with a flat and gently graded ground. Removing hazardous roadside features provides motorists with room and condition to regain control over their vehicle in case of a run-off. Objects that cannot be eliminated should be relocated outside the safety zone. The safety zone can be divided into two areas: the recovery zone (shoulders) and the limited severity zone (see Figure 16).

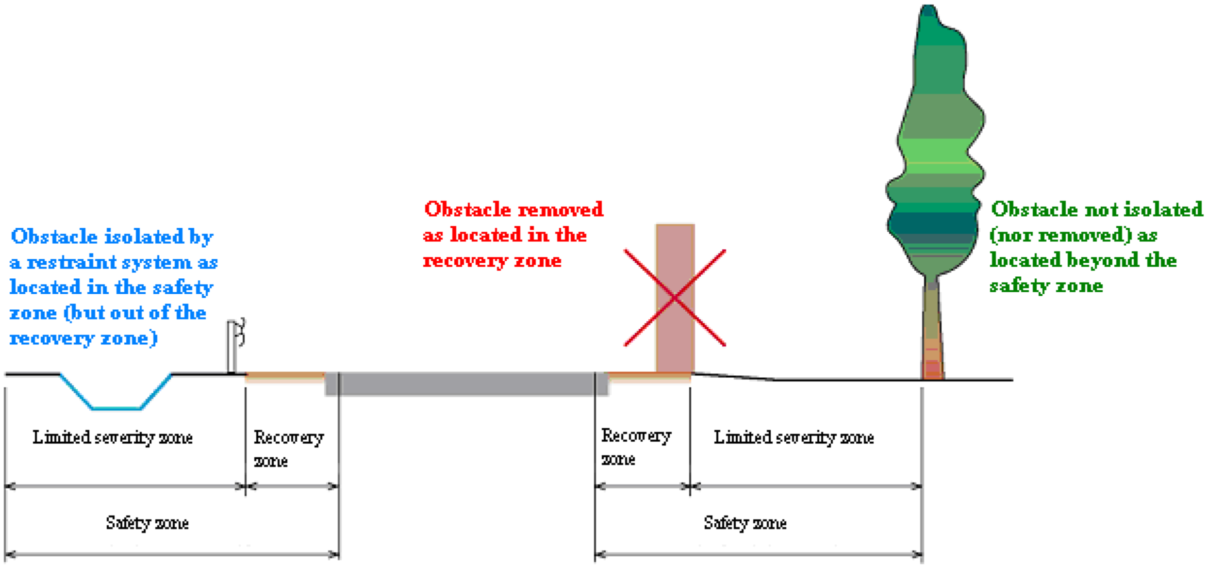


Figure 16: Safety zone definition, as depicted in [B.9]

Many national definitions do not distinguish between these two types of zones, only mentioning the need for a safety zone that may consist of a shoulder, a recoverable slope, a non-recoverable slope, as well as a clear run-out area. However, the two concepts are handled in separate chapters in this report.

The width of safety zones varies throughout the world depending on the underlying policy and practicability. Within the project RISER, the national dimensions for a safety zone of seven different European countries have been determined. Common criteria for the dimensioning are:

- Design speed
- Side slope gradients
- Road type
- Traffic flow/volume
- Horizontal alignment (straight or curved roads)
- Driving lane width
- Percentage of heavy-vehicles
- Evaluation of personal and third party risks

A detailed table of the dimensions depending on different parameters can be found in [A.3]. Generally, the higher the design speed, the wider the safety zone should be. The same relation is valid for curve radii. In [B.5], it is mentioned that safety zones also depend on traffic volumes. The widths dependent on speed limits, as defined in five different countries, are depicted in the diagram in Figure 17. In Sweden [B.16], a “good” safety zone lies between 3 and 14 meters, depending on curve radius and design speed. The width for safety zones on inner curves is generally lower than on outer curves. A study from Australia indicates that the desirable safety zone for straight high-trafficked roads with 100 km/h zones is 9 metres wide [B.5].

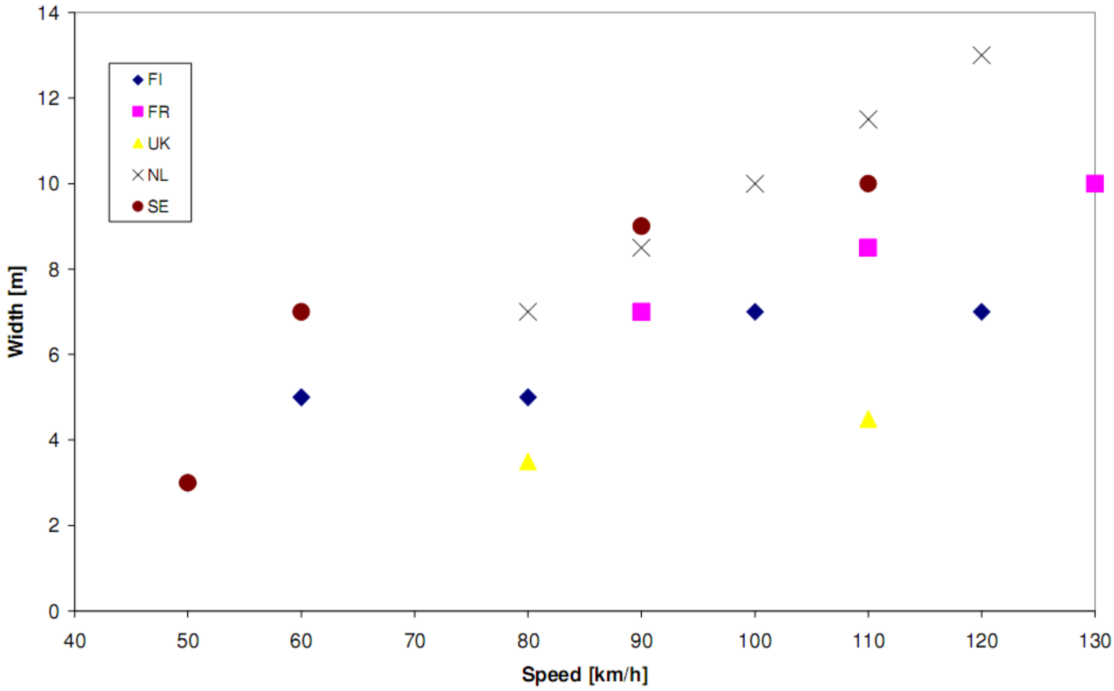


Figure 17: Safety zone widths as a function of speed limit for different countries [A.3]

The AASHTO Roadside Design Guidelines include a calculation method for clear zone widths, which is the most used worldwide. It is a function of the posted speed, side slope, and traffic volume. For further information see [B.1].

The government of Western Australia proposes a method, where the width of an appropriate safety zone (clear zone) is determined in three steps [B.5]:

1. Determine the desirable clear zone width (CZ) for a straight road based on the 85th percentile speed and the one-way traffic volume (see Figure 18). In general, the higher the speed and the AADT, the higher the zone width.
2. Multiply the CZ by an adjustment factor F_c, which is a function of operating speed and curve radius (see Figure 19). This factor increases with higher speeds and lower curve radii.
3. Compute a value called effective clear zone width (ECZ) that depends on the roadside slope gradients (see Figure 20). W_B is the batter width, W_1 is the width from the edge of the traffic lane to the beginning of the slope and W_2 is the width from toe of batter.

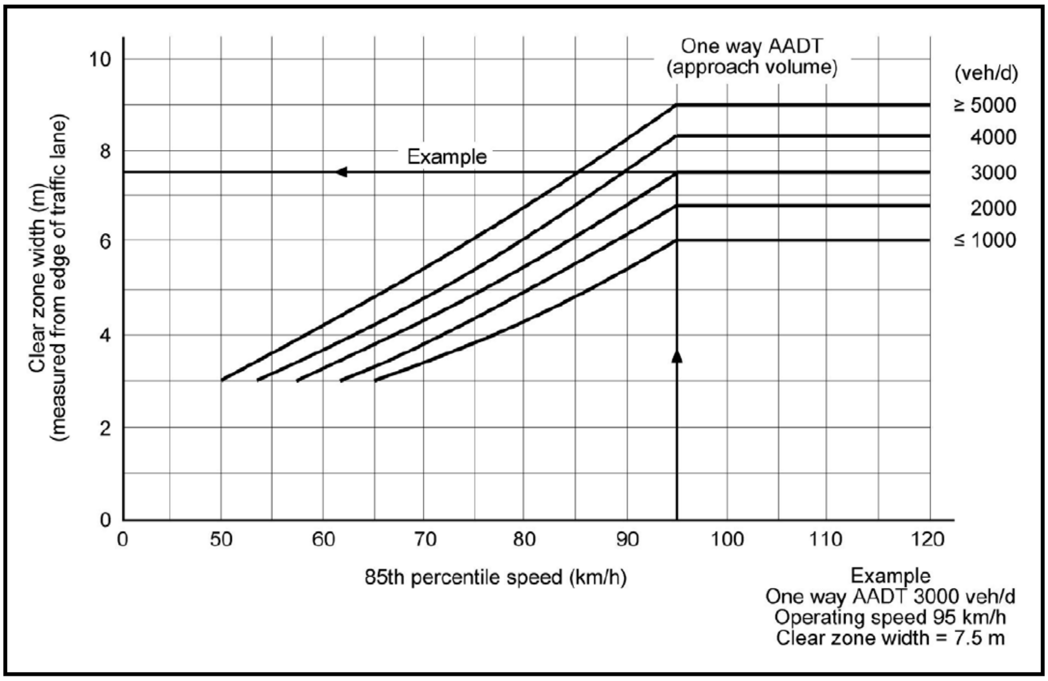


Figure 18: Clear zone distances based on 85th percentile speed and AADT [B.5]

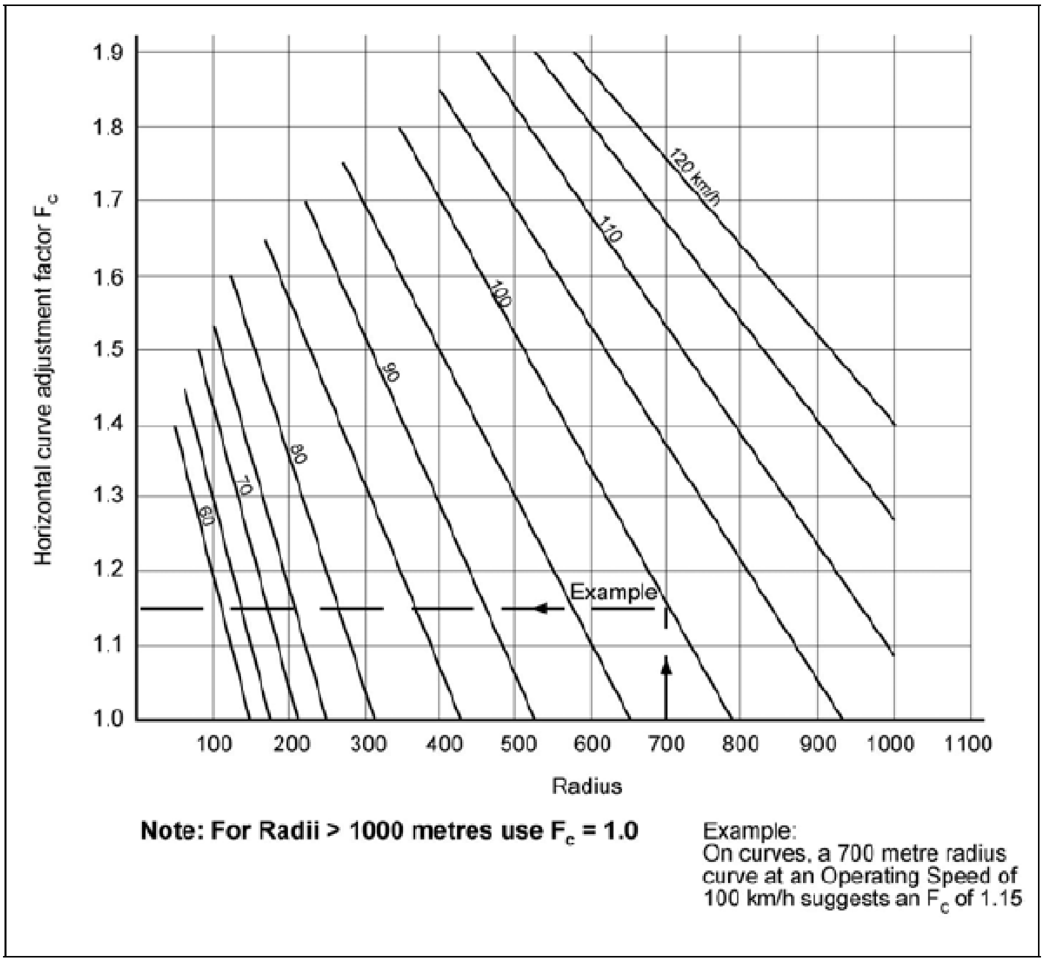


Figure 19: Curve adjustment factors to multiply with the clear zone width [B.5]

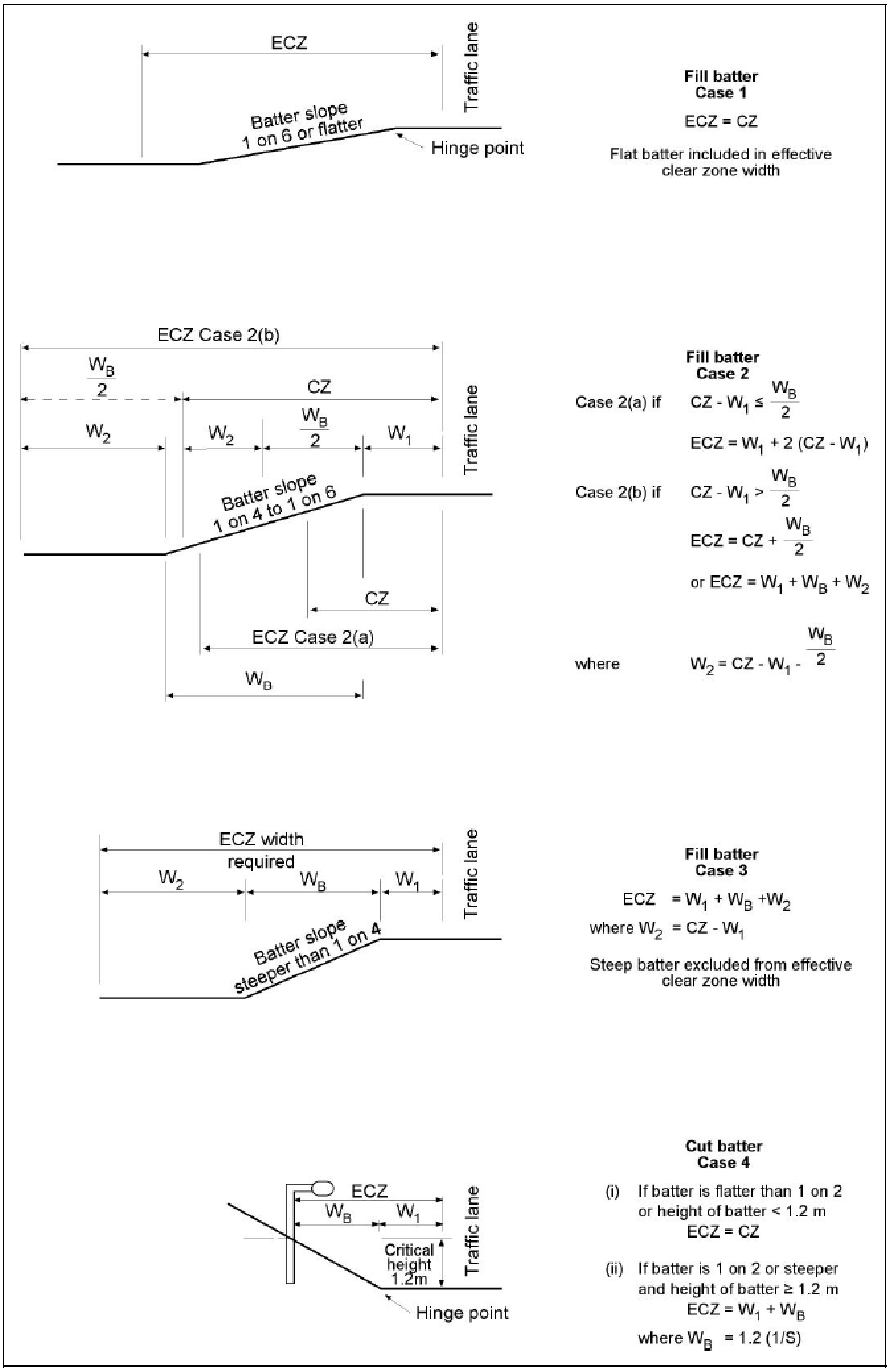


Figure 20: Calculation of the ECZ based on roadside slope [B.5]

3.1.1.1 Recovery area

According to [B.9], a recovery area is a side strip next to the pavement and is available for road users to perform easy recovery manoeuvres. It must be free of any obstacles so that drivers can return to the travel lane or can stop if necessary. The recovery zone is commonly defined as a hard or soft shoulder lane located immediately beyond the carriageway edge line. In Germany, the recovery zone is defined as a roadside shoulder area for emergency rescue services [A.3]. However, mostly it is not considered as a separate issue, but included in the total safety zone. Providing a recovery zone can comprise the following treatments:

- Hard shoulder construction
- Soft shoulder construction
- Enhancement of existing shoulders
- Median shoulders

A hard shoulder is a paved surface immediately beyond the carriageway edge line. The skid resistance of the surface should be as good as the carriageway surface in order to avoid skidding accidents. Hard shoulders are commonly used to provide emergency lanes, parking lanes, bicycle or pedestrian lanes. Several studies have proven the positive effect of hard shoulders on road safety. According to studies of Elvik and Vaa [A.12], rural roads with hard shoulders have an accident rate reduction of about 5 to 10 percent compared to rural roads without shoulders. An additional advantage of shoulders is the improved sight distances in curves.

Figure 21: Examples of a hard (left) and soft shoulder (right) (Source: [A.4])

Examples for shoulders are given in Figure 21. In contrast to hard shoulders, soft shoulders are unpaved areas beyond the paved carriageway e.g. in Austria [B.21], the width of unpaved shoulders depends on the travel lane width and lies between 0.25 and 0.5 metres. High drop-offs from paved to unpaved surfaces should be avoided, since they can be hazards in case of a run-off. However, this approach is not valid for roads with high level of traffic, where unpaved shoulders are not allowed. Other elements must be considered such as road geometry, space available, allocation of shoulder, traffic composition, etc.

The dimensions of shoulders have been heavily discussed among road engineers and safety experts. Instead of solely considering shoulder width as a safety aspect, the interdependencies between number of lanes and lane width need to be analysed. Wider shoulders may encourage higher driving speeds. For countries where the recovery zone is clearly stated as a separate issue, the widths vary between 0.25 and 4 metres, depending on the road type, travel lane width or design speed. Generally, the higher the design speed of the road, the wider the recovery zone. Based on the intended usage of the recovery zone, the widths are recommended between 1 to 1.5 metres for the recovery of errant vehicles and 3 to 4 metres for emergency lanes.

3.1.1.2 Limited severity zone

Some guidelines distinguish between the recovery area and the rest of the safety zone. The so-called limited severity zone does no longer attempt to prevent vehicles from leaving the road, but to minimize the severity in case of a run-off. It is defined as the area beyond the recovery zone, but is still part of the safety zone.

Figure 22: Broad limited severity zone, but narrow recovery area [B.9]

Any hazardous obstacle should be removed from this zone. This includes the removal of any single hazards such as poles, light supports or trees, as well as continuous hazards such as walls. Since the limited severity zone is not explicitly mentioned in most guidelines and standards, dimensions are not always provided. In some countries, the side slope gradient is taken into account for the zone width.

3.1.1.3 Median shoulders

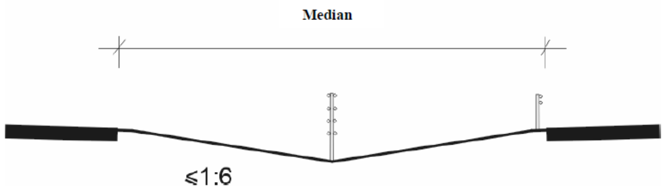
The median, also called central reserve, separates travel lanes for traffic in opposite directions. In most documents, it is not considered as part of the roadside, but as a separate issue. It is mentioned in this report though, because a median can reduce run-off-road accidents or minimize their severity. An additional benefit of medians includes the provision of recovery areas for errant vehicles and emergency stopping. In urban areas, medians are commonly used for pedestrian refuge and traffic control device placement. They can also be planted to improve the visual environment. Past research studies have found three safety trends regarding medians [A.14]:

1. Crashes between opposing vehicles are reduced with medians.
2. Median-related crashes decrease as the median width increases beyond 30 feet (9.1 metres). Up to 30 feet, the crashes increase as the median width increases.
3. The effect of median widths on total crashes is questionable.

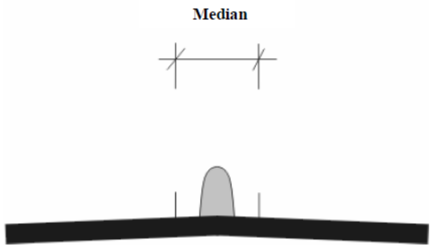
The recommended widths vary from country to country because they depend on the available space, as well as the intended use of the median. According to a Swedish Standard [B.16], medians can be divided into several types:

a) Median designed as slope, without barrier

b) Median between 1.5 and 2.5 metres with barrier



c) Median width >2.5 metres with barrier



d) Median between 1.5 and 2.5 metres with rigid barrier

Figure 23: Different types of medians [B.16]

When the median is designed as a slope (upper left picture in Figure 23a), the width can vary, but should be wide enough to separate both carriageways horizontally and in profile. A safety zone should be considered or barriers installed in order to prevent collisions with obstacles.

Figure 23b and Figure 23d depict medians with barriers between 1.5 and 2.5 metres. The two roadways have a common alignment, and the median between is typically paved.

Figure 23c shows a median greater than 2.5 metres with a barrier. The surface can be soft or paved and the slope gradient should not be steeper than 1:4.

A special type of median is a tunnel wall that separates two carriageways. The tunnel wall needs to fulfil the requirements on safety zones and barriers.

3.1.2 Arrester beds in lane diverge areas

Arrester beds in lane diverge areas are treatments for vehicles that have lost their braking ability. They are able to slow down and stop a vehicle going off the road without an impact against a crash cushion and are often used on roads with long downgrades e.g. in mountainous areas. They are also called emergency escape ramps or runaway truck lanes, because they are mainly designed to accommodate large trucks to prevent roadside accidents. The principal factor for the need of an arrester bed is determined by runaway accident experience. The ramps are often built before a critical change in the curvature of the road, or before a place that may require the vehicle to stop, such as an intersection in a populated area. The surface of the arrester bed is made of a specific material that increases rolling resistance and allows the vehicle to decelerate. Common arrester beds are composed of a layer of granular material of suitable aggregate size, shaped with geometry specifically designed to favour the sinking of vehicle wheels. Examples are given in Figure 24.

Figure 24: Examples for arrester beds [C.3]

There is a lack of specific guidelines dealing with the design or requirements of arrester beds. Typically, accident statistics, the relation between operation speed and road gradients or curvature are relevant for the construction of the ramp. To design an arrester bed, a detailed analysis is needed. Length will vary depending on speed and grade. The AASHTO developed a policy on geometric design of highways and streets, including design principles for escape ramps [B.24]. The length required by the ramp can be calculated using the equations in Figure 25.

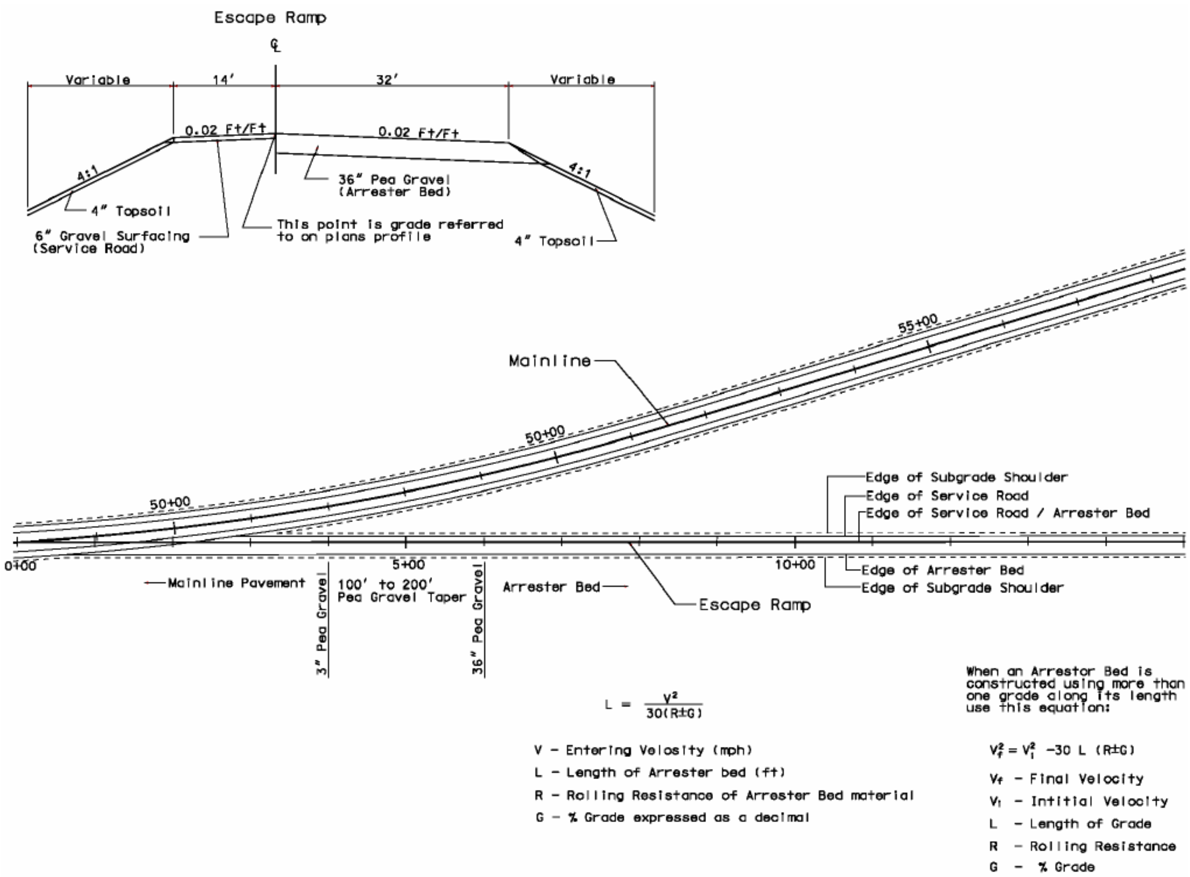


Figure 25: Escape ramp layout [B.24]

3.1.3 Safe plantation

Following the principle of safety zones, hazardous plants or trees should be removed from the specified roadside area. However, grass, weeds, brush and tree limbs can obscure or limit a driver's view of traffic control devices, approaching vehicles, wildlife and livestock, and pedestrians and bicycles. Even if hazardous plants have been removed from the roadside, the growth of plants and mature trees can lead to new roadside obstacles. Controlling vegetation therefore helps to reduce crashes and injuries. Road operators are encouraged to develop roadside vegetation management programs to eliminate or minimize vegetation. The FHWA of the U.S. Department of Transportation published a guideline for vegetation control, which includes several treatments such as regular mowing, cutting or the use of herbicides (see [B.6]). The NCHRP published a guide to eliminate tree crashes or to reduce the harm that results from a collision [B.3]. One major objective of this guideline is to prevent trees from growing in hazardous locations.

3.2 *Modifying roadside elements*

In some cases, hazardous obstacles cannot be removed from the roadside safety zone. Single and continuous hazards need to be modified in order to minimize injury or property damage at a crash. They must be improved by making them breakaway or crashworthy. The following chapters show different treatments to make non-removable objects more forgiving.

3.2.1 Breakaway devices

Since the 1980s, road authorities have installed collapsible lighting columns to increase roadside safety. The advantage is a smaller likelihood of impact damage and injury, while the disadvantage is the falling pole that can be a hazard to surrounding traffic, pedestrians or property. Non-breakaway poles are still used if pedestrian traffic is high, overhead electric lines are close or if the pole is mounted atop a concrete traffic barrier. However, breakaway poles are preferred in most roadside areas. There are several strategies to make poles or posts “forgiving”. This can be achieved by the following modifications:

- *Material use*: The most obvious way to increase the energy-absorbance is to use materials with low stiffness. Wooden poles or posts should therefore be avoided. A good compromise between energy-absorbance and safety are poles made of fibreglass that absorb the energy on its entire length. The pole cracks without having a predetermined breaking point.
- *Splicing*: Incorrect practices of predetermined breaking points can result in vehicle snagging and flying parts. In order to achieve a safe breakaway, splices should be kept close to the ground. According to [B.17], multiple splices should be avoided. An example is given in Figure 26.

Figure 26: Breakaway/spliced pole (left) and slip base (right) [C.4]

- *Slip-base poles*: A characteristic of slip base poles is that, when impacted at normal operating traffic speeds, they are generally dislodged from their original position (see Figure 27). It enables the pole to slip at the base and fall if a collision occurs.

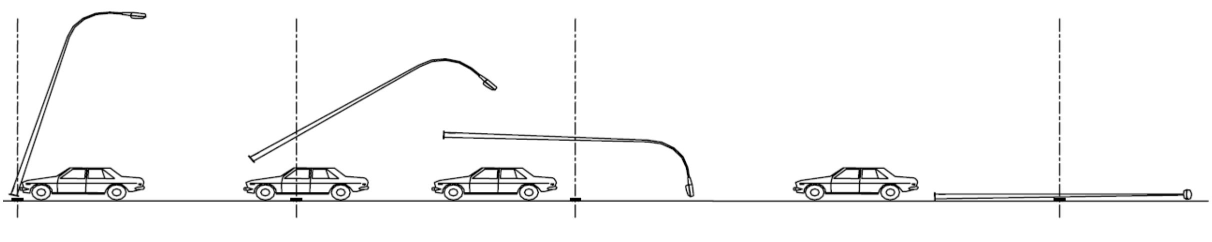


Figure 27: Vehicle impacting on a slip base pole [C.4]

- *Breakaway transformer base*: A transformer base, commonly made of cast aluminium, is bolted to a concrete foundation. The bottom flange of the pole is bolted to the top of the transformer base. The aluminium is heat-treated to make it "frangible," so that the pole can break away from the base when struck by a vehicle.
- *Breakaway connectors*: When breakaway poles are used, the electrical conductors must also be breakaway. This is accomplished by using special pull-apart fuse holders (breakaway connectors). In the case of breakaway poles, the neutral must also have this breakaway connector but should be unfused. Breakaway connectors are fused or unfused connectors in the base of poles.

The Texas Department of Transportation published a highway illumination manual (see [C.5]) that includes specific guidelines for the placement and use of breakaway devices. According to the manual, the falling area must be considered in the placement of breakaway poles. To prevent secondary accidents due to falling poles, they should be placed so that a sufficient falling area is ensured.

3.2.2 Ditch and slope treatments

Ditches are used as drainage features on roadsides. They usually consist of a foreslope, a ditch bottom with or without drainage features and a backslope. If ditches are considered hazardous, they need to be modified to increase safety. Based on the shape of the ditch, several treatments are state of the art:

- *Buried drainage*: Removing is imposed when the ditch is useless. Usually, drainage is necessary and thus cannot be removed. An effective treatment is to fill the ditch with draining materials after fitting a collector. This eliminates any hazardous sideslopes from the safety zone.
- *Modify slope ratio*: If a ditch cannot be removed, the slopes should be kept as shallow as possible. In general, the steeper the foreslope or backslope, the higher the risk for drivers of errant vehicles. So-called recoverable sideslopes permit the driver to regain control over the vehicle. Recoverable slopes have a slope ratio of 4:1 or flatter. For higher traffic volumes, sideslopes should be designed with a 6:1 ratio. Although the influence of backslopes is generally less than that of foreslopes, a ratio of 3:1 or flatter is recommended [B.2]. Examples for safe ditches are depicted in Figure 28.
- *Bottom modifications*: Ditch bottoms can either be sloped or flat. Thomson and Valtonen [A.17] investigated the behaviour of errant vehicles in V-shaped ditches. They proved that rounding the bottom prevents vehicles from a rollover. As a conclusion, they recommend a rounded bottom ditch with a foreslope of 4:1 and backslope 2:1.Ditches must be designed wide enough to provide adequate drainage and snow storage capacity. For reasons of safety, the width of the bottom should be at least 1 metre. In [B.2], a minimum width of 1.2 metres is preferred. Very shallow and wide ditch bottoms may require additional buried drainage.
- *Cover ditches*: Another common treatment is to cover the ditch with gutters or any other drainage system. This is particularly recommended at roadsides where a deep ditch is needed. Examples are given in Figure 29.
- *Modify masonry structures in ditches*: Ditches often include drainage features such as culverts, kerbs or control dams, which are made of rigid, non-energy-absorbent material. These structures need to be made crashworthy by modifying their shape.
- *Isolate most dangerous ditches*: Isolating ditches means to shield them from errant vehicles. The space required for an adequate road restraint system must be taken into account. This type of treatment is discussed in Chapter 3.3.
- *False cutting*: It is a shape of road embankment which is able to create a ground division between road section and external environment so that the roadside appears to drivers like a cutting, such as a linear artificial hill. This kind of artificial hill can also prevent the road to be seen from an external point of view.

In 2009 a Finish report on full-scale crash tests and simulations of ditches and slopes has been published. [A.18]

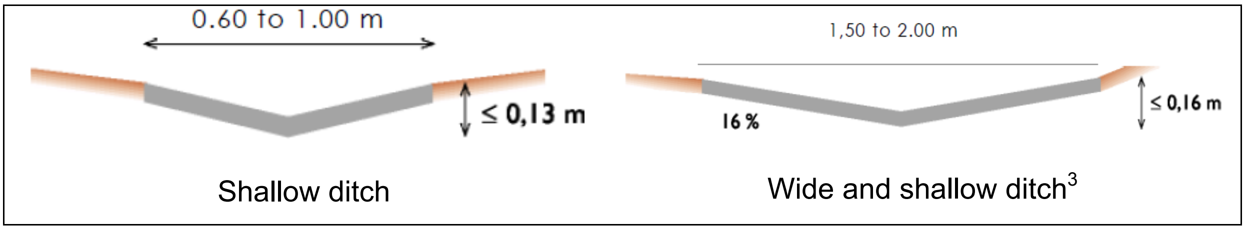


Figure 28: Examples for safe ditch design[B.9]

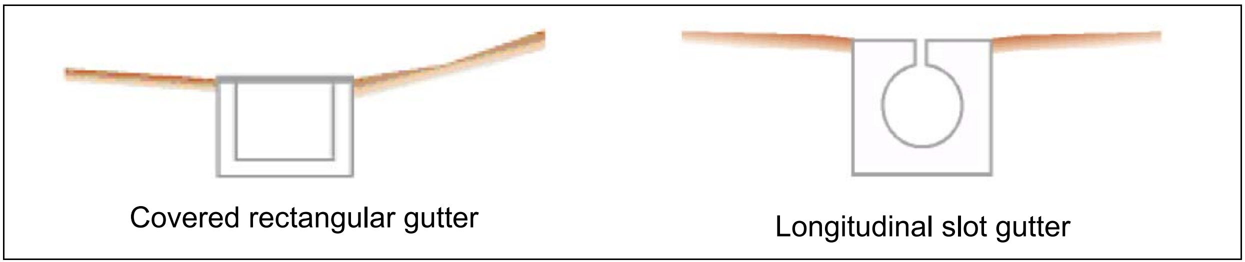


Figure 29: Examples for covering ditches [B.9]

3.2.3 Crashworthy masonry structures

Masonry structures such as parapets, culverts or kerbs can often be found on roadsides, especially at ditches or bridges. They generally have a minimal energy-absorbance and are thus very hazardous obstacles for errant vehicles. If they cannot be removed from the safety zone, these structure need to be modified in an appropriate manner. Other masonry structures such as bridge piers, walls or buildings, which cannot be removed or relocated, should be shielded with a road restraint system. Isolating or shielding the obstacles – which is the most appropriate strategy - is subject of Chapter 3.3. This chapter deals with treatments to modify masonry structures to make them crashworthy.

If a vehicle runs off the road into a ditch, culvert ends can be hazardous obstacles. If they cannot be removed, safer designs need to be considered. A common treatment for culvert ends is bevelling (see Figure 30).

Figure 30: Bevelled culvert end (left) and chamfered parapet (right) (Sources: [A.2], [B.9])

Short parapets, mostly found at bridges to protect errant vehicles from running off the slope, are hazardous due to their rigidness. If possible, they should be removed or replaced by a lighter barrier. However, in some cases modifying the structure of the parapets is a cheap and easy treatment. When the parapet is too short to protect errant vehicles, it should be

[3] In literature, the slope gradient is specified in different ways. Either ratios (e.g. 4:1, 1:4) or percentages are common.

extended to an adequate length. The ends of a parapet can be chamfered to minimize the aggressiveness in case of a collision (see Figure 30). Ideally, the ends have an offset to the outside. This kind of treatment can be applied to any other masonry structure that cannot be removed from the safety zone.

In this report, kerbs are also categorized as masonry structures. They serve as drainage control, pavement edge or walkway delineation. As mentioned in [B.9], kerbs are not considered as obstacles if their height does not exceed 20 cm. However, hitting a vertical kerb may cause an errant vehicle to mount or launch. Therefore, special design treatments of kerbs increase roadside safety. The Transportation Research Board published guidelines dealing with kerb and kerb-barrier installations [B.28]. When kerbs must be used on high-speed roads, the shortest possible kerb height and flattest slope should be used to minimize the risk of tripping the vehicle in a nontracking collision. The shape of the kerbs is a safety-relevant feature that depends on the operating speed of the roadway. Vertical kerbs should be used at low-speed roads, since they may cause vehicle roll-overs at high impact speeds. Sloping kerbs are configured such that a vehicle can safely ride over the kerb. They prevent vehicles from being redirected back into the traffic stream and are therefore the recommended option on highways and high-speed roads.

Figure 31: Vertical kerb (left) and sloping kerb (right)

Often, kerbs are used in combination with road restraint systems. In the scope of this report, kerb-barrier combinations have also been researched. The state of the art is presented in Chapter 3.3.6.

3.2.4 Shoulder modifications

Shoulder treatments that promote safe recovery include shoulder widening, shoulder paving, and the reduction of pavement edgedrops. Shoulders may not always be flush with the roadway surface. Such shoulder edgedrops can be caused by soil erosion next to the pavement, rutting by frequent tyre wear or from repaving, where material is added to the lane but not to the adjacent shoulder. This hazard needs to be treated by bevelling the edges or by levelling the pavements. It is common to slope the edge with an angle of 45 degrees [B.4].

If the skid resistance of a paved shoulder is insufficient, treatments to increase surface friction should be applied. Moreover, any other hazardous surface damages such as potholes or cracks need to be eliminated from the shoulder.

3.2.5 Modification of retaining walls and rock cuts

According to [B.9], a wall is acceptable in the safety zone when it meets the following conditions:

- longitudinal to the road or virtually (offset < 1/40th);
- no protrusion nor edge likely to block a vehicle, or better: smooth;
- heights over 70 cm;

- sufficiently sturdy to withstand an impact.

If a hazardous wall or continuous rock cannot be removed from the safety zone, its extremities need to be treated or isolated if possible. Rough walls or rocks must let the vehicle slide in case of an impact. Therefore, its surface is typically smoothed and cavities between protrusions are filled with masonry. Examples for wall treatments are depicted in Figure 32.

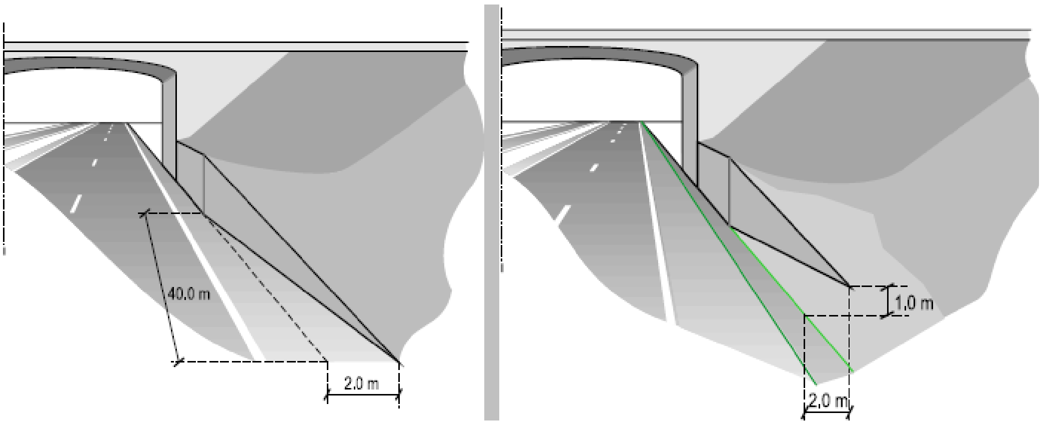


Figure 32: Example of end design of a retaining wall close to the carriageway[B.16]

3.2.6 Safety barrier terminals

Safety barriers belong to the group of road restraint systems and are explained in more detail Chapter 3.3, which deals with shielding measures for hazardous objects and locations. In some cases, modification of existing safety barrier terminals is necessary. First of all, two different types of terminals exist, which differ in their purpose. Terminals can be used to redirect vehicles back onto their original track or to stop them immediately, so that they cannot pass through the barrier [A.2]. Depending on the situation, one or the other type can be useful. If the terminals are aimed at stopping the vehicle these have to be treated as energy absorbing devices and have to be tested according to ENV 1317-4 (which will be superseded by the new EN1317-4 standard, as detailed in Appendix)

Especially when terminals appear as hazards, as explained in Chapter 3.3, countermeasures are necessary. For rigid barriers (see Chapter 3.3.1) the most probable way to modify the terminal is to make it semi-rigid (see Chapter 3.3.2). This causes the vehicle to crash into a deformable barrier first, which guides the vehicle onto the rigid one. The problem with this installation is the transition between the two barrier types, which will be handled in Chapter 3.2.7. The second option is to build them breakaway, so that for impacts the terminal breaks and swings back behind the barrier [B.22]. Also a deflection from the traffic lane towards the roadside is an appropriate measure, as can be seen in Figure 33.

Figure 33: Deflecting breakaway safety barrier terminal [B.22]

Another possibility to handle hazardous safety barrier terminals is to shield them separately by crash cushions, which will be handled in Chapter 3.3.6.

3.2.7 Safety barrier transitions

The transition between two safety barriers has to ensure that vehicles slide along the barrier in a smooth way, without any interruption. All necessary information about safety barriers and its types can be found in Chapter 3.3.

Especially between semi-rigid (see Chapter 3.3.2) and rigid barriers (see Chapter 3.3.1), the transition has to be stiff enough to ensure a change without snagging onto the rigid barrier [B.22]. This transition is depicted in Figure 34.

Figure 34: Transition between semi-rigid and rigid barrier [B.22]

The transition between a flexible barrier (see Chapter 3.3.3) and a semi-rigid barrier is commonly constructed by overlapping the flexible one in front. This leads vehicles to slide onto the semi-rigid barrier in a smooth way. The same installation can be used when flexible and rigid barriers are connected.

3.3 *Shielding obstacles*

In many cases removing or modifying hazardous objects is not possible or economically advisable. To prevent collisions of vehicles with these objects, the third option is to shield them by using road restraint systems (RRS). The hazardous object is fully protected, so that deviating vehicles crash into the RRS, which alleviate the consequences of the impact. These systems can appear as hazardous objects themselves, but the severity of occurring accidents should still be less than without RRS. They are divided into vehicle- and pedestrian-restraint systems as depicted in Figure 35.

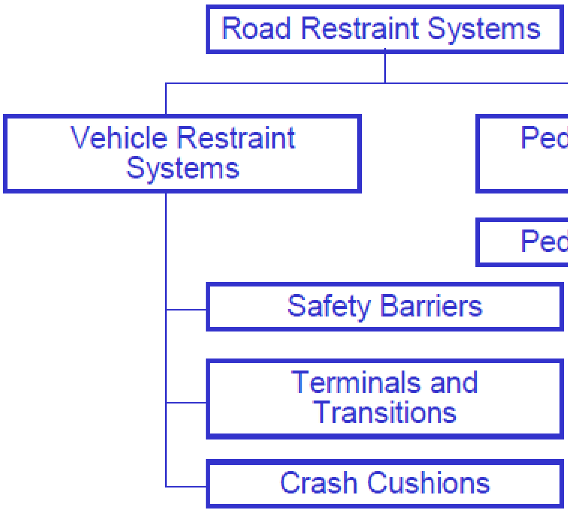


Figure 35: Classification of road restraint systems [A.13]

The most important group of RRS are safety barriers. They prevent errant vehicles from leaving the traffic lane and therefore minimize the probability to collide with a hazardous object. They can be installed either at the roadside or at the median. The purpose of RRS is to protect drivers and passengers of errant vehicles, as well as to prevent collision with opposing traffic. Moreover, pedestrians and cyclists are protected from getting onto the road or falling off a dip or into water. Besides the restrain function, another purpose is the redirection of vehicles onto their original path so that they can more easily continue their movement. The effectiveness of RRS is evaluated according to the following criteria:

- Containment level of RRS
- Impact severity
- Deformation or operating width

Safety barriers have to prevent vehicles from passing through, implying over- and underriding, while the severity of crashes should be reduced. This can be achieved by constructing the barrier deformable or moveable. Therefore safety barriers are divided according to their deflection level in following three main groups, which will be handled later on in detail.

- Rigid
- Semi- rigid
- Flexible

The criteria of deformation state that traffic barriers should also be intact after an impact and possible debris do not cause damages to vehicle occupants. Detailed requirements of RRS are regulated in the European Norm (EN) 1317. They are subdivided into following eight parts:

- Part 1: Terminology and general criteria for test methods [B.24]
- Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers [B.25]
- Part 3: Performance classes, impact test acceptance criteria and test methods for crash cushions [B.32]
- Part 4: Performance classes, impact test acceptance criteria and test methods for transitions of safety barriers (draft) – *spread “old” Part 4* [B.26]
- Part 5: Product requirements and evaluation of conformity for vehicle restraint Systems [B.27]
- Part 6: Pedestrian restraint system – Pedestrian Parapet [B.23]
- Part 7: Performance classes, impact test acceptance criteria and test methods for terminals of safety barriers (draft) – *spread “old” Part 4* [B.28]
- Part 8: Motorcycle road restraint systems which reduce the impact severity of motorcyclist collision with safety barriers (draft) [B.31]

More detailed information about each part can be seen in Appendix A. The EN 1317 is a tool to support the road planners with a standardized comparison of various RRS. It does not give advice on which RRS to take in specific situations. This is handled in guidelines like the RISER document [A.2].

The use of safety barriers and other restraint systems is usually subject to national regulations and standards. An example of a national standard (Italy) is summarized in Appendix.

3.3.1 Rigid barriers

Rigid barriers are commonly made out of concrete. Rigid barriers retain their shape and position when hit by a vehicle, leading to heavy impacts. They provide a high containment level without any deflection under impact. The advantage, on the other hand, is the small space consumption, since it does not deflect at all. This is especially of interest for median installations where the barrier is close to the traffic lane, as Figure 36 (left) shows.

Figure 36: Examples of rigid median barriers [B.22]

Typical applications are motorways with high speed, where total restraint is required. They show the best performance in terms of containment, with the disadvantage of higher injury risk.

3.3.2 Semi-rigid barriers

Semi-rigid barriers are the most common alternative to rigid barriers, since they usually cause less severe accidents. They are typically made out of steel. Semi-rigid barriers have two main functions. On the one hand, they prevent errant vehicles from passing through. On the other hand, they absorb the energy of the impact by deformation. This leads to less severe accidents and a better performance in terms of redirection. However, subsequent collisions with other vehicles or obstacles may occur due to redirection. The most commonly used type of semi-rigid barrier is the W-beam, which can be seen in Figure 37. Concrete modular barriers which can be deformed when hit by a vehicle are also considered as semi-rigid barriers.

Figure 37: A typical installation of a median W-beam [B.22]

3.3.3 Flexible barriers

Typical examples for flexible barriers are cable barriers and safety fences. Flexible barriers cause the least damage to vehicles, and pose the smallest risk of injury to vehicle occupants, compared to all other barrier types. The main disadvantage of flexible barriers is that they require more space behind them, since they can deflect by up to three metres. Also the slope in the area of deflection should be flat enough to ensure a secure redirection performance. Like semi-rigid ones, flexible barriers may cause crashes where a vehicle is deflected from a barrier, but subsequently collides with another vehicle or obstacle.

3.3.4 Temporary safety barriers

Temporary barriers are mainly used to shield construction sites from traffic and therefore have a limited lifetime. They are made out of steel, concrete and nowadays more often plastic polymers. One of the main differences between temporary and permanent barriers is the anchorage. Temporary barriers have to be placed individually, since working sites are only on restricted areas and only for restricted time periods. Hence they cannot be integrated in the road infrastructure as permanent barriers, which leads to the second difference that they do not offer the same level of protection. However, safety at working sites is mainly determined by other factors. On the one hand, the speed at these locations is lower (e.g. through speed limits), so that the impacts on barriers are initially lower. On the other hand, usually one or more lanes are closed, which leads to more careful driving behaviour.

Figure 38: Common temporary safety barriers (Sources: [B.22], [C.7])

3.3.5 Underriders

Steel safety barriers increase the likelihood of motorcyclists being injured or even killed. The problem is that motorcycles have no crush zone to reduce the impact of the vehicle on the barrier and that the rider usually fall off the bike during the accident. Typically, collisions with the posts of barriers are a main factor for injuries, when the rider slides into the restraint system. Other risk sources are the upper and lower edges, as well as too low a mounting height.

Another problem is that motorcyclists can slide through the barrier and crash into a hazardous object behind (e.g. tree, steep slope). Safety treatments are so-called underriders, which are mounted at the bottom of the barrier and prevent the motorcyclist from passing through the barrier, as well as appearing as shielding for posts and edges [B.20].

Figure 39: Example of underriders leading to a continuous shape (Source: [B.20])

Any underrider applied to a safety barrier will modify its behaviour. Under special circumstances, they could decrease the overall safety outcome of the protection system. Any barrier with an underrider will therefore have to be tested according to EN1317-8 (when available) or to national standard (as in Italy, Spain etc).

3.3.6 Kerb-barrier combinations

In the scope of this report, guidelines for the use of kerbs in conjunction with barriers as well as research papers dealing with safety of kerb-barrier combinations have been investigated. Generally, it is not desirable to use barriers alongside kerbs. Instead of installing barriers, safety zones free of any roadside obstacles are recommended. If concerns about drainage make them essential for proper highway maintenance, inadequate design of the kerb-barrier combination can result in overriding or underriding barriers. The following properties as well as their interdependencies need to be considered for improving roadside safety:

- Kerb height
- Kerb shape or slope
- Offset distance from kerb to barrier
- Barrier type
- Barrier height

According to [B.28], the roadside designer should consider a maximal kerb height of 100 mm when using barriers alongside. The kerb slope should be 1:3 (vertical : horizontal) or flatter. Barriers installed behind kerbs should not be located closer than 2.5 metres for any operating speed in excess of 60 km/h. This minimal distance is needed to allow the vehicle suspension to return to its pre-departure state, where impacts with the barrier should proceed successfully without vaulting it. However, in some European countries (e.g. Austria), it is common to place the kerb under the barrier, i.e. the kerb is flush with the face of the barrier. Figure 40 depicts a design chart for kerb-barrier combinations. Most roadside design guidelines do not recommend using rigid barriers in combination with kerbs.

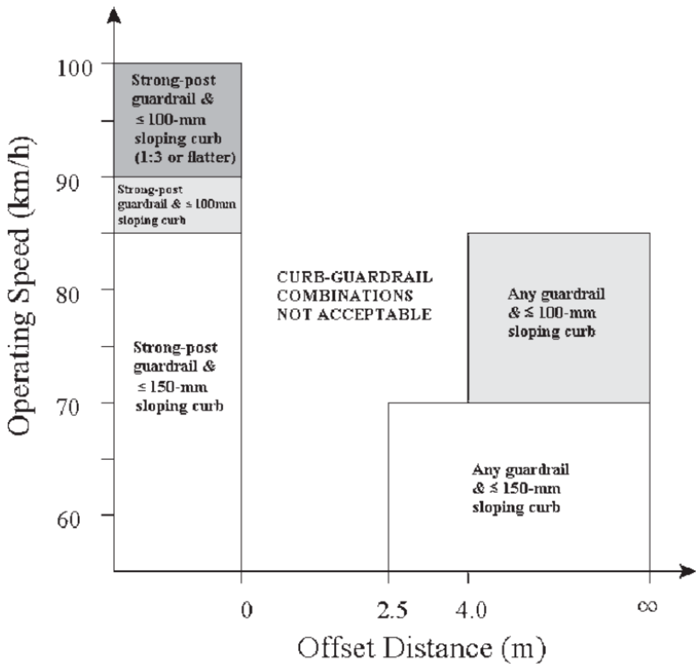


Figure 40: Kerb-barrier combinations by operating speed and offset distance [B.28]

3.3.7 Impact attenuators

Impact attenuators or crash cushions are restraint systems which are used to reduce the consequences of crashes with point obstacles. The protection of terminals and transitions can also be handled with this measure. They are typically protected in all directions, so that they can be better customised than barriers. In any case they should only be used if safety barriers are not possible at all or an appropriate installation cannot be reached.

Crash cushions can be distinguished by the absorption method used as follows:

- Multiple plastic boxes, made heavier by internal bags filled with salt, water or foam and connected with steel cables
- Sack devices, made from synthetic fibre sacks containing cylindrical sink elements, filled with expanded clay, linked together and leaning against lightened steel cusp
- Valved tubes, protected by sliding steel blades and connected with steel cables

Examples of common impact attenuators are depicted in Figure 41.

Figure 41: Examples of crash cushions (Sources: [A.3] and [C.4])

Several factors should be considered in the placement of impact attenuators. The attenuator should be placed on a level surface or on a slope no greater than 5 percent. The surface should be paved, bituminous or concrete without any kerbs in the surrounding of the attenuator. The orientation angle depends on the design speed or the alignment of the road.

4 Conclusion and recommendations

The first work package of the IRDES project deals with a collection and harmonization of current standards and studies regarding roadside design and forgiving roadsides. This deliverable comprises state-of-the-art treatments and strategies to make roadsides more forgiving. The goals of this report are to summarize existing treatments and to harmonize currently applied standards and guidelines. Three groups of treatments are discussed: Removing or relocating obstacles from the roadside, modifying roadside elements and shielding obstacles.

As a conclusion, it must be stated that removing obstacles is the primary strategy in most countries. Providing a so-called safety zone with a certain width allows drivers to regain control over their errant vehicle and to return to the travel lane or stop. Especially in the planning phase of a new road, safety zones should be considered. They should be free of obstacles with a flat and gently graded ground. Road operators are also encouraged to develop roadside vegetation management programs to eliminate or minimize vegetation. It is recommended to consider the safety zone width as a function of the posted speed, side slope, and traffic volume. However, some guidelines also include curve radii in their calculations. The AASHTO Roadside Design Guidelines introduce a calculation method for clear zone widths, which is the most used worldwide. It provides a useful basis for developing a uniform and practical guideline concerning forgiving roadside design, which is handled in WP3 of IRDES. Shoulders are named as recovery areas in this report. There exist several national standards regarding shoulder widths and their surface properties. A lack of standards concerning the so-called limited severity zone (the area beyond the shoulder) has been found.

If hazardous obstacles cannot be removed from the roadside safety zone, they need to be modified in order to minimize injury or property damage at a crash. Poles or supports are commonly made break-away and masonry structures (e.g. walls, curbs or buildings) are made crashworthy. There exist a high number of specifications to make obstacles more forgiving. In many national standard documents, certain side slope treatments are mentioned. In general, the steeper the slope, the higher is the risk for drivers of errant vehicles. Slopes should thus be kept as shallow as possible. For higher traffic volumes, side slopes should be designed with a 6:1 ratio. Ditches must be designed wide enough to provide adequate drainage and snow storage capacity. For reasons of safety, the width of the bottom should be at least one metre. Drainage features such as culvert ends or control dams need to be made crashworthy by modifying their shape. As there exist numerous different regulations for slope ratio and ditch characteristics, they should be harmonized with respect to proper drainage as well as its forgiving nature. Shoulder treatments that promote safe recovery include shoulder widening, shoulder paving as well as the reduction of pavement edge drops. If the skid resistance of a paved shoulder is insufficient, treatments to increase surface friction should be applied. Moreover, any other hazardous surface damages such as potholes or cracks need to be eliminated from the shoulder.

To prevent collisions of vehicles with obstacles, the third option is to shield them by using road restraint systems (RSS). In this deliverable, restraint systems are divided into safety barriers and impact attenuators. Safety barriers have to prevent vehicles from passing through, implying over- and underriding, while the severity of crashes should be reduced. This can be achieved by constructing the barrier deformable or moveable. Therefore, safety barriers are divided according to their deflection level in most guidelines and standards. Detailed requirements of RRS are regulated in the European Norm (EN) 1317. However, it does not give advice on which RRS to take in specific situations. This is handled in specific guidelines such as the RISER documents. Future uniform European guidelines should also include recommendations for kerb-barrier combinations as well as safe motorcycle restraint systems. Standards concerning these topics are currently under development. Impact attenuators or crash cushions (e.g. plastic boxes filled with sand or water) are restraint systems, which are used to reduce the consequences of crashes with point obstacles. The protection of terminals and transitions can also be handled with this measure. In some cases, modification of existing safety barrier terminals is necessary. If the terminals are aimed at stopping the vehicle these have to be treated as energy absorbing devices and have to be tested according to ENV 1317-4. In most reviewed guidelines, a deflection from the traffic lane towards the roadside is an appropriate measure to make terminals forgiving. The transition between two safety barriers has to ensure that vehicles slide along the barrier in a smooth way, without any interruption. It also has to be stiff enough to ensure a change.

The results of the literature review carried out in the scope of this report will be the basis for the development of a uniform and practical European guideline for roadside design. Moreover, the guideline is based on an assessment of the effectiveness of different treatments, which is part of work package 2 within IRDES.

The large number of possible treatments to make a road forgiving shows the large potential of those systems for increasing road safety. A harmonization helps road operators and authorities in their decisions to plan safe roads. Common road planning procedures together with Road Safety Audit or Road Safety Inspections on existing roads, have to include the specific view on forgiving roadsides.

Glossary

Arrester bed
An area of land adjacent to the roadway filled with a particular material to decelerate and stop errant vehicles; generally located on long steep descending gradients.

Back slope (see ditch)
A slope associated with a ditch, located opposite the roadway edge, beyond the bottom of the ditch.

Boulder
A large, rounded mass of rock lying on the surface of the ground or embedded in the soil in the roadside, normally detached from its place of origin.

Break-away support
A sign, traffic signal or luminaire support designed to yield or break when struck by a vehicle.

Abutment
The end support of a bridge deck or tunnel, usually retaining an embankment.

Vehicle parapet (on bridges)
A longitudinal safety barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure. It can be constructed from either steel or concrete.

CCTV Masts
A mast on which a closed circuit television camera is mounted for the purpose of traffic surveillance.

Carriageway
The definition of the ‘carriageway’ differs slightly amongst countries. The edge of the carriageway is delineated by either the “edge line” or, if no edge line is present, the edge of the paved area.

Central reserve
An area separating the carriageways of a dual carriageway road.

Clearance
The unobstructed horizontal dimension between the front side of safety barrier(closest edge to road) and the traffic face of the.

Clear/Safety zone
The area, starting at the edge of the carriageway, that is clear of hazards. This area may consist of none or any combination of the following: a ‘hard strip’, a ‘shoulder’, a recoverable slope, a non-recoverable slope, and/or a clear run-out area. The desired width is dependent upon the traffic volumes, speeds and on the roadside geometry.

Contained vehicle
A vehicle which comes in contact with a road restraint system and does not pass beyond the limits of the safety system.

Containment level
The description of the standard of protection offered to vehicles by a road restraint system. In other words, the Containment Performance Class Requirement that the object has been manufactured and tested to (EN 1317).

Crash cushion
A road vehicle energy absorption device (road restraint system) installed in front of a rigid object to contain and redirect an impacting vehicle ("redirective crash cushion") or to contain and capture it ("non-redirective crash cushion").

Culvert
A structure to channel a water course. Can be made of concrete, steel or plastic.

Culvert end
The end of the channel or conduit, normally a concrete, steel or plastic structure.

Cut slope
The earth embankment created when a road is excavated through a hill, which slopes upwards from the level of the roadway.

Design speed
The speed which determines the layout of a new road in plan, being the speed for which the road is designed, taking into account anticipated vehicle speed on the road.

Distributed hazards
Also known as 'continuous obstacles', distributed hazards are hazards which extend along a length of the roadside, such as embankments, slopes, ditches, rock face cuttings, retaining walls, safety barriers not meeting current standard, forest and closely spaced trees.

Ditch
Ditches are drainage features that run parallel to the road. Excavated ditches are distinguished by a fore slope (between the road and the ditch bottom) and a back slope (beyond the ditch bottom and extending above the ditch bottom).

Divided roadway
Roadway where the traffic is physically divided with a central reserve and/or road restraint system. Number of travel lanes in each direction is not taken into account. See also ‘dual carriageway’.

Drainage gully
A structure to collect water running off the roadway.

Drop-off
The vertical thickness of the asphalt protruding above the ground level at the edge of the paved surface.

Dual carriageway
A divided roadway with two or more travel lanes in each direction, where traffic is physically divided with a central reserve and/or road restraint system. See also 'divided roadway'.

Edge line
Road markings that can be positioned either on the carriageway surface itself at the edge of the carriageway, or on the 'hard strip' (if present) next to the carriageway.

Embankment
A general term for all sloping roadsides, including cut (upward) slopes and fill (downward) slopes (see 'cut slope' and 'fill slope').

Encroachment
A term used to describe the situation when the vehicle leaves the carriageway and enters the roadside area.

Energy absorbing structures
Any type of structure which, when impacted by a vehicle, absorbs energy to reduce the speed of the vehicle and the severity of the impact.

Fill slope
An earth embankment created when extra material is packed to create the road bed, typically sloping downwards from the roadway.

Frangible
A structure readily or easily broken upon impact (see also 'break-away support').

Fore slope (see ditch)
The fore slope is a part of the ditch, and refers to the slope beside the roadway, before the ditch bottom.

Forgiving roadside
A forgiving roadside mitigates the consequence of the "run-off" type accidents and aims to reduce the number of fatalities and serious injuries from these events.

Guardrail
A guardrail is another name for a metal post and rail safety barrier.

Hard/Paved shoulder
An asphalt or concrete surface on the nearside of the carriageway. If a 'hard strip' is present, the hard shoulder is immediately adjacent to it, but otherwise, the shoulder is immediately adjacent to the carriageway. Shoulder pavement surface and condition as well as friction properties are intended to be as good as that on the carriageway.

Hard strip
A strip, usually not more than 1 metre wide, immediately adjacent to and abutting the nearside of the outer travel lanes of a roadway. It is constructed using the same material as the carriageway itself, and its main purposes are to provide a surface for the edge lines, and to provide lateral support for the structure of the travel lanes.

Highway
A highway is a road for long-distance traffic. Therefore, it could refer to either a motorway or a rural road.

Horizontal alignment
The projection of a road - particularly its centre line - on a horizontal plane.

Impact angle
For a longitudinal safety barrier, it is the angle between a tangent to the face of the barrier and a tangent to the vehicle's longitudinal axis at impact. For a crash cushion, it is the angle between the axis of symmetry of the crash cushion and a tangent to the vehicle's longitudinal axis at impact.

Impact attenuators
A roadside (passive safety) device which helps to reduce the severity of a vehicle impact with a fixed object. Impact attenuators decelerate a vehicle both by absorbing energy and by transferring energy to another medium. Impact attenuators include crash cushions and arrester beds.

Kerb (Curb)
A unit intended to separate areas of different surfacings and to provide physical delineation or containment.

Lane line
On carriageways with more than one travel lane, the road marking between the travel lanes is called the 'lane line'.

Limited severity zone
An area beyond the recovery zone that is free of obstacles in order to minimize severity in case of a vehicle run-off.

Length of need
The total length of a longitudinal safety barrier needed to shield an area of concern.

Median
See 'central reserve'.

Motorways
A dual carriageway road intended solely for motorized vehicles, and provides no access to any buildings or properties. On the motorways itself, only grade separated junctions are allowed at entrances and exits.

Nearside
A term used when discussing right and left hand traffic infrastructure. The side of the roadway closest to the vehicle's travelled way (not median).

Non-paved surface
A surface type that is not asphalt, surface dressing or concrete (e.g. grass, gravel, soil, etc).

Offside
A term used when discussing right and left hand traffic infrastructure. The side of the roadway closest to opposing traffic or a median.

Overpass
A structure including its approaches which allows one road to pass above another road (or an obstacle).

Paved shoulder
See ‘hard shoulder’.

Pedestrian restraint system
A system installed to provide guidance for pedestrians, and classified as a group of restraint systems under ‘road restraint systems’.

Pier
An intermediate support for a bridge.

Point Hazard
A narrow item on the roadside that could be struck in a collision, including trees, bridge piers, lighting poles, utility poles, and sign posts.

Recovery zone
A zone beside the travel lanes that allows avoidance and recovery manoeuvres for errant vehicles.

Rebounded vehicle
A vehicle that has struck a road restraint system and then returns to the main carriageway.

Retaining wall
A wall that is built to resist lateral pressure, particularly a wall built to support or prevent the advance of a mass of earth.

Road restraint system (RRS)
The general name for all vehicle and pedestrian restraint systems used on the road (EN 1317).

Road equipment
The general name for structures related to the operation of the road and located in the roadside.

Road furniture
See ‘road equipment’.

Roadside
The area beyond the roadway.

Roadside hazards
Roadside hazards are fixed objects or structures endangering an errant vehicle leaving its normal path. They can be continuous or punctual, natural or artificial. The risks associated with these hazards include high decelerations to the vehicle occupants or vehicle rollovers.

Roadway
The roadway includes the carriageway and, if present, the hard strips and shoulders.

Rock face cuttings
A rock face cutting is created for roads constructed through hard, rocky outcrops or hills.

Rumble strip (Shoulder rumble strips)
A thermoplastic or milled transverse marking with a low vertical profile, designed to provide an audible and/or tactile warning to the road user. Rumble strips are normally located on hard shoulders and the nearside travel lanes of the carriageway. They are intended to reduce the consequences of, or to prevent run-off road events.

Rural roads
All roads located outside urban areas, not including motorways.

Safety barrier
A road vehicle restraint system installed alongside or on the central reserve of roads.

Safety zone
See ’clear zone’.

Self-explaining road
Roads designed according to the design concept of self-explaining roads. The concept is based on the idea that roads with certain design elements or equipment can be easily interpreted and understood by road users. This delivers a safety benefit as road users have a clear understanding of the nature of the road they are travelling on, and will therefore expect certain road and traffic conditions and can adapt their driving behaviour accordingly. (Ripcord-Iserest, Report D3, 2008).

Set-back
Lateral distance between the way and an object in the roadside for clearance).

Shoulder
The part of the roadway between the carriageway (or the hard strip, if present) and the verge. Shoulders can be paved (see 'hard shoulder') or unpaved (see 'soft shoulder').
Note: the shoulder may be used for emergency stops in some countries; in these countries it comprises the hard shoulder for emergency use in the case of a road with separate carriageways.

Single carriageway
See 'undivided roadway'.

Slope
A general term used for embankments. It can also be used as a measure of the relative steepness of the terrain expressed as a ratio or percentage. Slopes may be categorized as negative (fore slopes) or positive (back slopes) and as parallel or cross slopes in relation to the direction of traffic.

Soft/Unpaved shoulder
A soft shoulder is defined as being a gravel surface immediately adjacent to the carriageway or hard strip (if present). In some countries it is used as an alternative for hard shoulders.

Soft strip
A narrow strip of gravel surface located in the roadside, beyond the roadway (normally beyond a hard strip/shoulder).

Termination (barrier)
The end treatment for a safety barrier, also known as a terminal. It can be energy absorbing structure or designed to protect the vehicle from going behind the barrier.

Transition
A vehicle restraint system that connects two safety barriers of different designs and/or performance levels.

Travel/Traffic lane
The part of the roadway/carriageway that is travelled on by vehicles.

Treatment
A specific strategy to improve the safety of a roadside feature or hazard.

Underpass
A structure (including its approaches) which allows one road or footpath to pass under another road (or an obstacle).

Underrider
A motorcyclist protection system installed on a road restraint system, with the purpose to reduce the severity of a PTW rider impact against the road restraint system.

Undivided roadway
A roadway with no physical separation, also known as single carriageway.

Unpaved shoulder
See 'soft shoulder'.

Vehicle restraint system
A device used to prevent a vehicle from striking objects outside of its travelled lane. This includes for example safety barriers, crash cushions, etc. These are classified as a group of restraint systems under 'road restraint systems'.

Verge
An unpaved level strip adjacent to the shoulder. The main purpose of the verge is drainage, and in some instances can be lightly vegetated. Additionally, road equipment such as safety barriers and traffic signs are typically located on the verge.

Vertical alignment
The geometric description of the roadway within the vertical plane.

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Appendix

Summaries of EN documents (EN 1317 parts 1 to 8 and EN 12767)

The European Standard **EN 1317** consists of the 8 parts (some are under preparation).

- EN 1317-1, *Road restraint systems - Part 1: Terminology and general criteria for test methods*;
- EN 1317-2, *Road restraint systems - Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers including vehicle parapets*;
- EN 1317-3, *Road restraint systems - Part 3: Performance classes, impact test acceptance criteria and test methods for crash cushions*;
- ENV 1317-4, *Road restraint systems — Part 4: Performance classes, impact test acceptance criteria and test methods for terminals and transitions of safety barriers*;
- prEN 1317-4, *Road restraint systems − Part 4: Performance classes, impact test acceptance criteria and test methods for transitions of safety barriers* (under preparation: this document will supersede ENV 1317-4 for the clauses concerning transitions)*;*
- EN 1317-5, *Road restraint systems − Part 5: Product requirements and evaluation of conformity for vehicle restraint systems*;
- prEN 1317-6, *Road restraint systems − Pedestrian restraint systems — Part 6: Pedestrian Parapet* (under preparation);
- prEN 1317-7, *Road restraint systems − Part 7: Performance classes, impact test acceptance criteria and test methods for terminals of safety barriers* (under preparation: this document will supersede ENV 1317-4 for the clauses concerning terminals);
- prEN 1317-8, *Road restraint systems - Part 8: Motorcycle road restraint systems which reduce the impact severity of motorcyclist collisions with safety barriers* (under preparation).

EN12767
Passive Safety of support structures for road equipment – Requirements and test methods

EN1317-1

Introduction:
In order to improve and maintain highway safety, the design of safer roads requires, on certain sections of road and at particular locations, the installation of road restraint systems to restrain vehicles and pedestrians from entering dangerous zones or areas. The road restraint systems designated in this standard are designed to specify performance levels of containment and to redirect errant vehicles and to provide guidance for pedestrians or other road users.
The standard identifies impact test tolerances and vehicle performance criteria that need to be met to gain approval. The design specification, for road restraint systems entered in the test report, should identify the on-road site conditions under which the road restraint system should be installed.

The performance range of restraint systems, designated in this standard, enables National and Local Authorities to recognize and specify the performance class to be deployed. The range of possible vehicular impact scenarios in an on-road road restraint system is extremely large in terms of speed, approach angle, vehicle type, vehicle attitude, and other vehicle and road conditions. Consequently the actual on-road impacts which occur may vary considerably from the specific standard test conditions. However, adequate implementation of the standard should identify the characteristics, in a candidate safety road restraint system that is likely to achieve maximum safety and reject those features which are unacceptable.

Manufacturers may wish to modify their products following the test and clause n. 5.2, 6.2.1.5 and Annex A in EN 1317-5: 2006 set out the procedure to be followed.
Manufacturers may wish to place their products in Families, as system type tested products, and clauses 4.7 in EN 1317-2: 2010, 5.5 in EN 1317-3: 2010 and in ENV 1317-4: 2002 set out the procedure to be followed.
The modifications included in this part of the standard are not a change of test criteria, in the sense of the Annex ZA.3 of Part 5.

Scope:

This standard contains provisions for the measurement of performance under impact and impact severity levels and includes:

- Test site data
- Definitions for road restraint systems; other parts of the standard may add to these
- Vehicle specifications including loading requirements for vehicles used in the impact tests
- Instrumentation for the vehicles
- Calculation procedures and methods of recording crash impact data including impact severity levels
- VCDI mandated measurements (VCDI is not a mandated requirement)
- Informative Annexes

<u>EN1317-2</u>

Introduction:
This standard includes improved impact test procedures and allows for the introduction of Families of Products and a Part 2 report template.

In order to improve safety the design of roads may require the installation of safety barriers including parapets which are intended to contain and redirect errant vehicles safely for the benefit of the occupants and other road users on sections of road and at particular locations defined by the National or Local Authorities.
In this standard, several levels of performance are given for the three main criteria relating to the restraint of a road vehicle:

- the containment level;
- the impact severity levels;
- the deformation as expressed by the working width.

The different performance levels of safety barriers including parapets will enable National and Local Authorities to specify the performance class of the system to be deployed. Factors to be taken into consideration include the class or type road, its location, geometrical layout, the existence of a vulnerable structure, potentially hazardous area or object adjacent to the road.

The description of a safety barrier including parapet system conforming to this Standard

incorporates the relevant classes and performance levels of the product.
To ensure satisfactory product design it is imperative to consider the requirements of this standard and the references in clause 2, together with the requirements of EN 1317-1: 2010. Quality of manufacture, installation and durability must fulfil the requirements of EN 1317-5:2006.

Manufacturers may wish to modify their products following the ITT and clause nos. 5.2, 6.2.1.5 and Annex A in EN 1317-5:2006 set out the procedure to be followed. The modifications included in this part of the standard are not a change of test criteria, in the sense of the Annex ZA.3 of Part 5.

Scope:
This European standard shall be read in conjunction with EN 1317-1. These two standards support EN 1317-5.
This standard specifies requirements for:

- Impact performance of safety barriers and vehicle parapets
- Classes of containment and impact severity levels

EN1317-3

Introduction:
Based on safety considerations, the design of roads may require the installation of crash cushions at certain locations. These are designed to reduce the severity of vehicle impact with a more resistive object.

One objective of this standard is to lead to the harmonisation of current national standards and/or regulations for crash cushions and to categorize them into performance classes.

The standard specifies the levels of performance, required of crash cushions, for the restraint and/or redirection of impacting vehicles. The impact severity of vehicles in collision with crash cushions is rated by the indices Theoretical Head Impact Velocity (THIV), and Acceleration Severity Index (ASI) (see EN 1317-1).

The different performance levels will enable national and local authorities to specify the performance class of crash cushions. The type or class of road, its location, its geometrical layout, the existence of a vulnerable structure or potentially hazardous area adjacent to the road are factors to be taken into consideration.

Attention is drawn to the fact that the acceptance of a crash cushion will require the successful completion of a series of tests (see Table 1, 2, 3, etc.).

This European Standard is a supporting standard to EN 1317-5, which shall be read in conjunction with EN1317-1. Manufacturers may wish to modify their products following the ITT, and clause numbers 5.2, 6.2.1.5 and Annex A in EN1317-5 set out the procedure to be followed.

The modifications included in this part of the standard are not a change of test criteria, in the sense of the Annex ZA.3 of Part 5.

Scope:
This European Standard specifies requirements for the performance of crash cushions from vehicle impacts. It specifies performance classes and acceptance criteria for impact tests.

ENV1317-4

This is a preliminary standard which was aimed at specifying test methods for terminals and transitions. This standard has been discharged and will be replaced by EN 1317-4 for transitions and EN1317-7 for terminals. Until the new EN1317-4 and EN1317-7 will be published ENV1317-4 is commonly used for testing energy absorbing terminals.

prEN1317-4

Introduction:
In order to improve safety the design of roads may require the installation of safety barriers including parapets which are intended to contain and redirect errant vehicles safely for the benefit of the occupants and other road users on sections of road and at particular locations defined by the National or Local Authorities. Problems may also arise in the connection between two different safety barriers having consistent difference in design and/or in stiffness. Transitions are required to provide a smooth and safe change from one barrier to the other.

This standard specifies the direction of impact, and the methods for determining the critical impact points, for the testing of transitions.
Methods for designing transitions without specific crash tests are also included in the standard as well as criteria to apply tested transitions to different products without the need for repeating the crash tests.

Scope:
This European Standard is a supporting standard to EN1317-5 and shall also be read in conjunction with EN1317-1.

This Part completes Part 2 of the standard because it specifies performance for transitions, considered as the linkage between safety barriers of different types.

This Standard also defines acceptance criteria for impact tests and test methods.

EN1317-5

Introduction:
This document is a product standard for vehicle restraint systems placed on the market.

This document is designed for use in conjunction with Parts 1, 2, 3, prEN 1317-6 or ENV 1317-4. To ensure the full performance of road restraint systems in use, their production and installation is intended to be controlled in accordance with this document.

Scope:
This standard includes requirements for the evaluation of conformity of the following road restraint systems produced:

- safety barriers;
- crash cushions;
- terminals (will be effective when ENV 1317-4 becomes an EN);
- transitions (will be effective when ENV 1317-4 becomes an EN);
- Vehicle / Pedestrian Parapets (only for the vehicle restraint function)

Pedestrian parapet requirements are not covered in this standard.

Requirements for the evaluation of durability with respect to weathering are included in this standard.

Requirements for other forms of durability (e.g. Marine environment, sand abrasion) are not included.

Temporary barriers are not within the scope of this standard.

<u>prEN1317-6</u>

Introduction:
The safety considerations of pedestrians using road bridges and footbridges and similar structures that require the installation of special road restraint systems: pedestrian parapets.

Pedestrian parapets are provided and designed to restrain and to guide pedestrians and other non-vehicle road users including cyclists and equestrians.

Aspects included in the standard are:

- Safety in use for pedestrians and other highway users (excluding motor vehicles),
- The safety considerations of pedestrians using road bridges and footbridges and similar structures
- Analysis and test methods,
- Durability,
- Evaluation of the Conformity.

Scope:
This European Standard EN 1317-6 specifies geometrical and technical requirements and defines the requirements for design and manufacture of pedestrian parapets on bridges carrying a road or cycle path or footpath/bridleway or on top of retaining walls and other similar elevated structures.

This European Standard does not cover the requirements for:

- Vehicle restraint systems or pedestrian restraint systems in residential, commercial or industrial buildings and within their perimeter,
- Non rigid rails ie rope, cables,
- Transparency,
- Risks relating to the climbing of children.

This European Standard covers pedestrian parapets placed on the market as kits.

NOTE 1: The authorities for railways, rivers and canals can have additional special requirements.
NOTE 2: The above requirements for pedestrian restraint systems are normally defined in National Regulations or referenced in the project specification (or documentation).

prEN1317-7

Introduction:
The design purpose of safety barriers installed on roads is to contain errant vehicles that either leave the carriageway or are likely to encroach into the path of oncoming vehicles. EN 1317-2 deals with the impact performance of a safety barrier to which a terminal may be attached.

Terminals, which are defined as the beginning and/or end treatment of a safety barrier, are required to have specified impact performances without introducing additional hazards for passenger cars.

The description of a terminal conforming to this Standard incorporates the relevant classes and performance levels of the product.

Manufacturers may wish to modify their products or use them with different barriers following the ITT and clauses 5.2, 6.2.1.5 and Annex A of EN1317-5:2008 set out the procedure to be followed.

Scope
This European Standard is a supporting standard to EN1317-5 and shall also be read in conjunction with EN1317-1.

This Part completes Part 2 of the standard because it specifies performance for terminals, considered as the end treatment of a safety barrier.

This Standard also defines acceptance criteria for impact tests and test methods.

prEN1317-8

Introduction:
In order to improve safety the design of roads may require the installation of road restraint systems, which are intended to contain and redirect errant vehicles safely for the benefit of the occupants and other road users, or pedestrian parapets designed to restrain and to guide pedestrians and other road users not using vehicles, on sections of road and at particular locations defined by the national or local authorities.

Part 2 of this standard contains performance classes, impact test acceptance criteria and test methods for barriers. Whereas the aforementioned part covers the performance of these systems with respect to cars and heavy vehicles, this part of the standard addresses the safety of the riders of powered two-wheeled vehicles impacting the barrier having fallen from their vehicle.
As powered two-wheeler riders may impact a barrier directly (in which case no protection is offered by the vehicle) special attention is given to these vulnerable road-users. In order to minimise the consequences to a rider of such an impact, it may be necessary to fit a barrier with a specific PTW rider protection system. Alternatively, a barrier might specifically incorporate characteristics limiting the consequences of a PTW rider impact.

Rider protection systems may be continuous (including barriers specifically designed with the safety of PTW riders in mind) or discontinuous. A discontinuous system is one which offers rider protection in specific localised areas judged to be of higher risk. The most common example of a discontinuous system is one fitted locally to the posts of a post and rail type guardrail - adding nothing between the posts.

The purpose of this part of the standard is to define the terminology specific to it, to describe procedures for the initial type-testing of rider protection systems and to provide performance classes and acceptance criteria for them.

Accident statistics from several European countries have shown that riders are injured when impacting barriers either whilst still on their vehicles or having fallen and then sliding along the road surface. Whilst different statistical sources show one or the other of these configurations to be predominant, all known studies show both to constitute a major proportion of rider to barrier impact accidents. Some studies showing the sliding configuration to be predominant have led to the development and use of test procedures in some European countries, evaluating systems with respect to the sliding configuration. At the time of writing, a number of such protection systems were already on the European market. It is for this reason that it was decided to address the issue of sliding riders initially, in order to bring about the adoption of a European standard in as timely a manner as possible. However, the rider on vehicle configuration should also be considered as soon as possible for a subsequent revision of this part of the standard.

Scope:
This part of the European standard shall be read in conjunction with EN 1317 parts 1 and 2. These parts of the standard all support EN1317-5.

This part of the standard specifies requirements for the impact performance of PTW rider protection systems to be fitted to barriers or for the rider protection aspect of a barrier itself. It excludes the assessment of the vehicle restraint capabilities of barriers and the risk that they represent to the occupants of impacting cars. The performance of impacting vehicles must be assessed according to EN 1317 parts 1 and 2.

This part of the standard defines performance classes taking into account rider speed classes, impact severity and the working width of the system with respect to rider impacts.

For systems designed to be added to a standard barrier, the test results are valid only when the system is fitted to the model of barrier used in the tests. EN 1317-5 describes how it may be determined whether other barrier models are sufficiently similar to the barrier tested to allow their use in conjunction with the tested system without the need for additional testing. Guidelines for making this judgement are given in Annex G.

EN 12767

The severities of accidents for vehicle occupants are affected by the performance of support structures for items of road equipment under impact. Based on safety considerations, these can be made in such a way that they detach or yield under vehicle impact.

This European Standard provides a common basis for testing of vehicle impacts with items of road equipment support.

This European standard considers three categories of passive safety support structures:

- high energy absorbing (HE);
- low energy absorbing (LE);
- non-energy absorbing (NE).

Energy absorbing support structures slow the vehicle considerably and thus the risk of secondary accidents with structures, trees, pedestrians and other road users can be reduced.

Non-energy absorbing support structures permit the vehicle to continue after the impact with a limited reduction in speed. Non-energy absorbing support structures may provide a lower primary injury risk than energy absorbing support structures.

In this European Standard, several levels of performance are given using the two main criteria related to the performance under impact of each of the three energy absorbing categories of support structure. Support structures with no performance requirements for passive safety are class 0.

There are four levels of occupant safety:
Levels 1, 2 and 3 provide increasing levels of safety in that order by reducing impact severity. For these levels two tests are required:

- test at 35 km/h to ensure satisfactory functioning of the support structure at low speed.
- test at the class impact speed (50, 70 and 100) as given in Table 1.

Level 4 comprises very safe support structures classified by means of a simplified test at the class impact speed.

All the tests use a light vehicle to verify that impact severity levels are satisfactorily attained and compatible with safety for occupants of a light vehicle.

The different occupant safety levels and the energy absorption categories will enable national and local road authorities to specify the performance level of an item of road equipment support structures in terms of the effect on occupants of a vehicle impacting with the structure. Factors to be taken into consideration include:

- perceived injury accident risk and probable cost benefit;
- type of road and its geometrical layout;
- typical vehicle speeds at the location;
- presence of other structures, trees and pedestrians;
- presence of vehicle restraint systems.

Example for a national standard in Italy

Since 1992 a mandatory standard is in place in Italy to provide instruction for the design, construction and use of safety barriers and other road restraint systems (the Ministry Decree 223/1992).

The most recent update of the Italian national standard is the Ministry Decree 2367/2004 issued on the 21th of June of 2004. This decree has adopted in the EN 1317 standards for testing barriers to be used on public roads in Italy.

The Italian national regulation defines the minimum containment level of safety barriers to be used for different type of roads and different locations on the road section as defined in the following table:

Type of road	Type of traffic	Traffic barrier	Edging barrier	Bridge barrier
Motorways (A) and primary rural roads (B)	I II III	H2 H3 H3-H4	H1 H2 H2-H3	H2 H3 H4
Secondary rural Roads (C) and Urban arterials (D)	I II III	H1 H2 H2	N2 H1 H2	H2 H2 H3
urban distribution roads (E) and local roads (F)	I II III	N1 H1 H2	N1 N2 H1	H2 H2 H2

Type of traffic is defined according to the following table:

Type of traffic	Average annual daily traffic	% vehicles with mass >3.5 t
I	≤1000	Any
I	> 1000	≤ 5
II	> 1000	5 < n ≤15
III	> 1000	> 15

The areas to protect with safety barriers and other road restraint systems must include, at least:

- the margins of all open-air structures such as bridges, viaducts, underpasses and roadway support walls, independently from their longitudinal extension and their height from the ground; the protection must be extended for a suitable distance beyond the longitudinal development of the structure until it reaches points (both before and after the structure) from which the risk of severe consequences deriving from the exiting of vehicles from the roadway can be reasonably excluded;

- the median for divided carriageways. According the Italian Ministry Decree 5 November 2001 for the design of new roads a median has to be protected if the width of the median deducted the width of the left shoulders is less then 12m;

- road edges in sections with embankments with an height over the ground greater than or equal to 1 m and slopes greater than or equal to 2/3. For embankments lower than 1 m and for higher embankments with slope less than 2/3, the need for safety barriers depends on the combination of the slope and its height, considering situations of possible danger downstream of the slope (the presence of buildings, railway lines, dangerous material deposits or similar);

- fixed obstacles (frontal or lateral) that could endanger road users upon impact, for example bridge piers, emerging rocks, drainage systems that cannot be crossed, trees, street lighting and non frangible sign supports, waterways, etc, and other structures such as public or private buildings, schools, hospitals, etc. which would be endangered by an errant. These obstacles and buildings must be protected if it is not possible or convenient to relocate them and if they are at distance from the roadway edge shorter than a safety distance; this distance is not given in the national standard and it has to be defined by the designer considering, for example, the following parameters: design speed, traffic volume, road radius of curvature, embankment slope, obstacle type.

According to the Italian standard the safety barriers terminals can be either designed to avoid frontal hits with the barrier or energy absorbing devices tested according to ENV1317-4.

An UNI technical specification (UNI TR 11370 "Dispositivi stradali di sicurezza per motociclisti - Classi di prestazioni, modalità di prova e criteri di accettazione") has recently been published (July 2010) for testing safet barriers and underriders for motorcycle impacts.