Road Traffic
Management Corporation

# Draft Guideline Document

# South African Road Restraint Systems Manual (SARRSM)

March 2022

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DECADE OF ACTION FOR
ROAD SAFETY
2021 - 2030

**'Safe roads in South Africa'**

The Road Traffic Management Corporation is an Agency of the Department of Transport and a Member of the United Nations Road Safety Collaboration

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# Prelude

This Draft Guideline document, in its current format, was endorsed by the National Road Traffic Engineering Committee (NRTETC) and the National Road Safety Steering Committee (NRSSC) to be used by professionally registered road engineering practitioners until it is approved by the Committee of Transport Officials (COTO) as a Technical Methods for Highways (TMH) document. The document will follow the COTO approval process for TRH/TMH documents as outlined below.

| **COTO TRH/TMH DOCUMENT APPROVAL PROCESS** | |
|---|---|
| **STEP** | **REMARKS** |
| Step 1 | 1.1 COTO Subcommittee identify needs for new or revision of existing TRH/TMH<br>1.2 Panel Industry Experts appointed to assist |
| Step 2 | 2.1 COTO subcommittee and Industry experts draft new TRH/TMH number revisions<br>2.2 Once satisfied draft submitted to Roads Coordinating Body (RCB) for wider circulation and comments - Workshop held |
| Step 3 | 3.1 All comments received, reviewed, and incorporated where applicable<br>3.2 Final draft TRH/TMH prepared and submitted to RCB for approval recommendation to COTO |
| Step 4 | 4.1 Final draft submitted to COTO approval as "Draft TRH/TMH<br>4.2 Approved "Draft" released to wider industry for implementation |
| Step 5 | 5.1 Approved "Draft" TRH/TMH then introduced to industry through workshops<br>5.2 Approved" Draft'' TRH/TMH utilised in industry for 2-year period and comments/feedback provided to COTO subcommittee |
| Step 6 | 6.1 At the end of 2-year period all comments received are collated and industry workshop held to review all comments received and incorporated where applicable<br>6.2 COTO subcommittee then prepare final TRH/TMH |
| Step 7 | 7.1 Final TRH/TMH then submitted to RCB to recommend approval to COTO<br>7.2 COTO approval of final TRH/TMH |
| Step 8 | 8.1 Final TRH/TMH released to industry<br>8.2 TRH/THM use for minimum of 5 years before revision considered |

Notes:

1. A Draft Standard (DS) is approved by the RCB and implemented in Industry for a period of two (2) years, during which written comments may be submitted to the COTO subcommittee. A Draft Standards (DS) has full legal standing.

2. Final Standard (FS). After the two-year period, comments received are reviewed and where appropriate, incorporated by the COTO subcommittee. The document is converted to a Final Standard (FS) and submitted by the Roads Coordinating Body (RCB) to for approval as a final standard. This Final Standard is implemented in industry for a period of five (5) years, after which it may again be reviewed. Final Standards (FS) have full legal standing.

3. Standards (DS) have full legal standing.

4. The DoT assumes responsibility for the development of a web-based data management support system for the processing, management and warehousing of RAMS data.

5. Road users experience the same road standards throughout South Africa through the uniform application of COTO technical policies and standards.

# Foreword

Compiled and published under the auspices of the:
Road Traffic Management Corporation (RTMC)
(RTMC Requisition: 2003092)

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This document, comprising its several parts, is provided as a preliminary document without any warranty of any kind expressed or implied. No warranty or representation is made, either expressed or implied, with respect to fitness of use and no responsibility will be accepted by the RTMC or the authors for any losses, damages or claims of any kind, including, without limitation, direct, indirect, special, incidental, consequential or any other loss or damages that may arise from the use of the document.



Existing publication:
This document consists of two volumes:

Volume 1: South African Road Restraint Systems Manual (SARRSM)
Volume 2: South African Road Restraint Systems Manual Standards and Requirements

Comments:
Comments on this Draft Standard should be provided in writing and e-mailed to the Road Traffic Management Corporation.

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Please note:
This document and its various parts will only be published in electronic format.

# VOLUME 1 : South African Road Restraint Systems Manual (SARRSM )

## Contents

# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ASI | Acceleration Safety Index |
| AASHTO | American Association of State Highway and Transportation Officials |
| B/C | Benefit-Cost Ratio |
| COTO | Committee of Transport Officials |
| DC | Direct Cost |
| EN | European Norm |
| HGV | Heavy Goods Vehicle |
| LDV | Light Delivery Vehicle |
| MASH | Manual of Assessing Safety Hardware |
| NCHRP | National Co-operative Highway Research Programme |
| NMT | Non-Motorised Transport |
| NR | Non-Redirected |
| PHD | Post-Impact Head Deceleration |
| R | Redirected |
| RAPSA | Risk Assessment Procedure For South Africa |
| RRS | Road Restraint Systems |
| RTMC | Road Traffic Management Corporation |
| SC | Societal Crash Costs |
| SABS | South African Bureau of Standards |
| SANS | South African National Standards |
| SANRAL | South African National Roads Agency SOC |
| SARRSM | South African Road Restraint System Manual |
| SARSM | South African Road Safety Manual |
| SARTSM | South African Road and Traffic Signs Manual |
| SI | Severity Index |
| THIV | Theoretical Head Impact Velocity |
| USA | United States of America |
| WRSB | Wire Rope Road Safety Barrier |

## IMPORTANT NOTE

This Guideline Document, or sections thereof, may be applied in road development, road rehabilitation and maintenance projects and as part of road authorities' road network management programme.

The proposed periods within which the principles of this document should be applied for different road classes and project types are tabled below.

| PROJECT TYPE OR ROAD MANAGEMENT PROGRAMME | PERIOD FOR IMPLEMENTATION (YEARS) | | | | |
|---|---|---|---|---|---|
| | Class 1 | Class 2 | Class 3 | Class 4 | Class 5 |
| 1. Road development (new and upgrades) and rehabilitation. | 3 | 4 | 5 | 5 | 5 |
| 2. Maintenance projects. | 4 | 5 | 6 | 7 | 9 |
| 3. Removal and protection of identified hazards and maintenance of infrastructure during inter alia:<br>• network assessment;<br>• road safety initiatives;<br>• road management programmes;<br>• routine maintenance; and<br>• routine inspections.<br>(e.g. trees, bridge piers, fences and boulders and suchlike within the road reserve). | 5 | 6 | 7 | 8 | 10 |
| 4. Modification of minor drainage in- and outlet structures. | 10 | 10 | 12 | 15 | 15 |

It is proposed that road authorities incorporate the assessment of road restraint systems in the procedures and requirements of integrated transport plans and road management systems.

This documeht, in its current format should only be used by professionally registered road engineering practitioners.

# SOUTH AFRICAN ROAD RESTRAINT SYSTEMS MANUAL (SARRSM)

The main aim of road restraint systems (RRS) is to contain and redirect errant vehicles to avoid injury to occupants and reduce the damage to vehicles and infrastructure. The SARRSM is part of the South African Road Safety Manual (SARSM) series of documents that have been developed to assess or audit road safety conditions, identify areas that require improvement and provide guidance to improve road safety on the South African road network, including the installation of RRS.

The SARRSM is a technical guideline to assist road authorities and practitioners responsible for the planning and design of roads and is not intended to address the duty or responsibility of road authorities.

RRS forms an integral part of the road planning and design process and requires detailed knowledge of civil, transportation and traffic engineering and road safety principles.

RRS entails both vehicle restraint systems and pedestrian restraint systems and includes the following infrastructure elements:

- Safety barrier with the necessary terminals and transition sections;
- Vehicle parapets;
- Crash cushions;
- Arrestor beds;
- Measures to restrict the entry of vehicles;
- Pedestrian barriers, handrails and guardrails; and
- Pedestrian parapets.

A vehicle restraint system functions on several levels:

- Initially, it provides a visual indicator that overshooting the roadway is a risk;
- Next, it deflects a colliding vehicle, returning it to a safe path (redirect); and
- Finally, it sacrificially absorbs the impact of the errant vehicle (contain).

**Barriers should be a lesser hazard than that which they are intended to mitigate.**

Planning and design of RRS should consider the following:

- **The geometry of the road –** e.g. single or dual carriageway or motorway, lane configuration, design parameters and peripheral road risk factors;
- **The area to be protected (viewed as having different sections) –** e.g. curved/straight. Each of these requires different treatment;
- **The composition and rate of flow of the traffic –** e.g. vehicle types and the quantity and proportional mix with the peaks of both speed and volume. It should be taken into consideration that RRS elements have not been designed and tested for all situations that may occur on the road, and the limitations of such elements must be considered in the selection and design of RRS;
- **The road environment** – e.g. adjacent land use and activities along the road; and
- **Alternative risk treatment –** e.g. removing, adapting or relocating an element, thus affecting its potential impact on traffic safety.

# 1 INTRODUCTION

Road user safety has evident economic consequences in terms of property damage and loss of earnings or production resulting from a physical injury – in addition to the emotional consequences of pain, suffering and death. An essential but often overlooked part of every road is its roadside. Safety and economics are the twin foundation stones on which thoughtful designs rest. There are no natural substitutes for physical distance, flat slopes and clear verges. The principle applies that prevention is better than cure.

Barriers are a compromise between the conflicting demands of construction cost and safety; however, they themselves are also a hazard. **Therefore, to be warranted, the barrier or other form of RRS should be a lesser hazard than the hazard they are intended to prevent.**

An essential warrant for barrier installation is an adverse crash history when assessing the risk to errant vehicles on existing roads. In the case of new roads, it is necessary to consider whether the outcome of a crash is likely to be more severe without the barrier than with them.

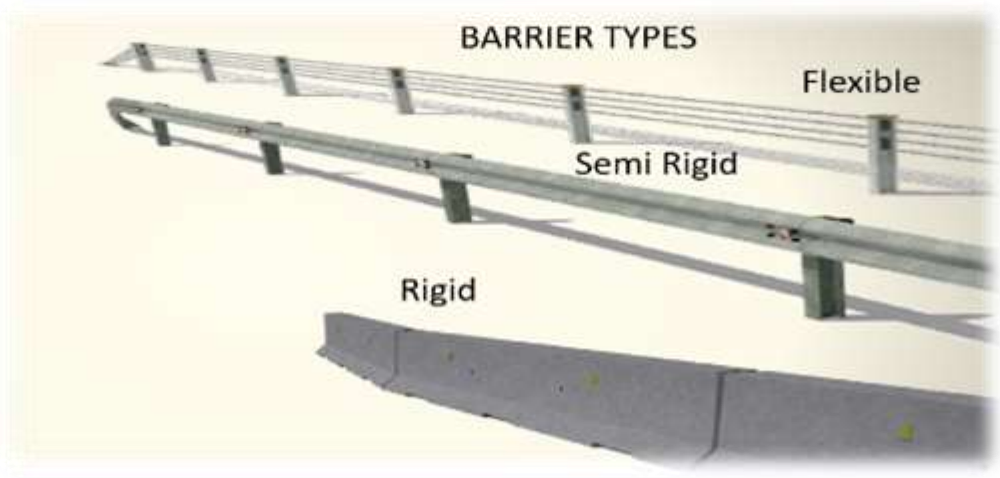
RRS is an element of all credible road design guides and has also been included in the Committee of Transport Officials (COTO) TRH 17 Geometric Design of Rural Roads and Standard Specifications for Road and Bridge Works. The SARRSM has been developed with references to the relevant sections of the COTO Specifications to assist in implementing RRS infrastructure.

The seriousness of crashes resulting from the absence of a barrier or the barrier itself is measured in terms of a severity index. This index compares the cost of such a crash with that of a property-damage-only crash. Errant vehicles seldomly travel more than 10 m beyond the edge of the carriageway, and there should be no hazardous obstruction in this area (referred to as the *clear zone*). The ideal would always be to remove hazards from this clear zone; if they cannot be removed, barriers may be warranted, depending on the extent of the hazard presented by the obstruction.

**The purpose of this document is to contribute to creating a more forgiving roadside and address the following:**

- **How to identify a roadside hazard according to the clear zone concept;**
- **How best to investigate a roadside hazard and to determine the warrant for a RRS; and**
- **How to select the most appropriate RRS treatment for the site.**

Crash data are a valuable source of information to improve road safety. Available crash data were taken into consideration in the development of the SARRSM. The collection and reporting of crash data should be expanded and improved to refine the procedures proposed in this manual, particularly those contained in Volume 2, Annexure A: *Risk Assessment Procedure*.



# 2 HAZARD MITIGATION

The first step towards making a roadside safer is identifying the roadside hazard. This task requires judgement and experience backed by sound engineering principles and informed by scientific data. It is essential to seek uniformity and consistency in defining roadside hazards as an industry pursuit.

**WHAT IS A ROADSIDE HAZARD?**

A roadside hazard is **any feature or object within the clear zone** along the side of the road that may adversely affect the safety of a vehicle that runs off the road. Treatment of hazards includes the provision of a safe environment for secondary road users such as pedestrians, cyclists and other non-motorised transport (NMT).

Common roadside hazards include the following:

**A roadside hazard is any feature or object within the clear zone.**

- Trees and landscape features;
- Non-breakaway signposts, support and poles (for lighting, utilities, signage, etc.);
- Drainage structures such as culverts and drains drop inlets;
- Bridge piers and similar objects;
- Side slopes such as embankments;
- Ends of traffic barriers, bridge railings;
- Roadside furniture;
- SOS boxes, fire hydrants, camera systems, etc.;
- Public transport infrastructure;
- Pedestrian facilities; and
- Bodies of water.

Bridge piers

Overhead signs

Street Lightning

Trees next to road 1

Drainage Stucture

**THE MITIGATION PROCESS**

It is accepted in road design that no road is entirely safe because, in the driving task, there is always a risk of damage to property or injury to persons. For existing roads, roadside-safety improvement involves removing or treating hazards that may result in a crash or contribute to the severity of a crash. In the case of new roads, a safer roadside is achieved by ensuring that an adequate clear zone is provided immediately adjacent to the road. This clear zone is free of obstacles and designed so that drivers can regain control of their vehicles. In addition, it is desirable to provide a clear width adjacent to the carriageway to allow all errant vehicles to recover. However, this is often not feasible, and it is necessary to provide RRS to redirect and contain vehicles to avoid collisions and thereby mitigate the damage to property and injury to people.

The risk assessment and mitigation process of crashes is illustrated in Figure 1 and expanded upon in the subsections to follow.

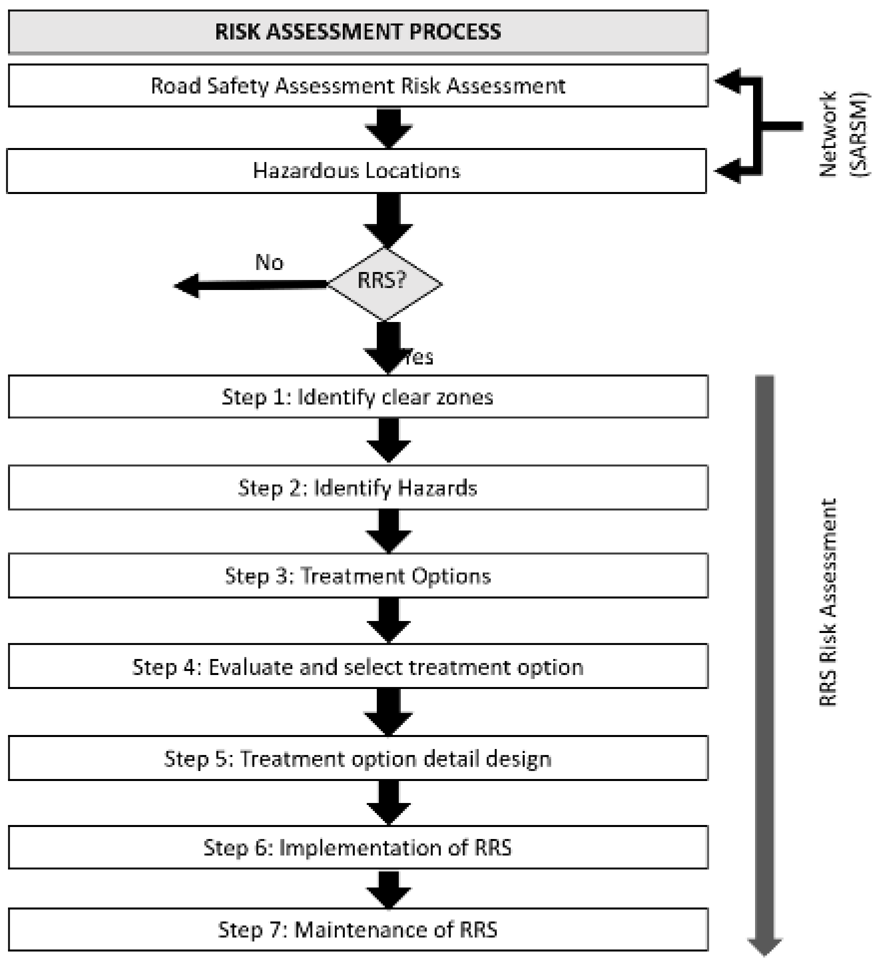



Figure 1: Hazard Mitigation Process in the RRS Environment

## 2.1 STEP 1: IDENTIFY CLEAR ZONES

A forgiving roadside reduces the consequences for vehicle occupants of a run-off-road crash and can be achieved by providing a clear zone alongside the roadway. The concept of a clear zone was developed to define an area that reduces the probability of a crash occurring at a site. The clear zone concept and underlying principles provide a risk management approach to prioritise the treatment of roadside hazards. The process of optimising the clear zone distance provides a balance between a sufficient recovery area for errant vehicles and the cost of providing this area.

**The clear zone is the total fixed-object-free area available to errant vehicles and falls within the recovery zone area, which is the total unobstructed traversable area available along the edge of the road.**

The clear zone width is dependent on:

- Speed;
- Traffic volumes;
- Side slopes; and
- Horizontal geometry – clear zones may be widened on horizontal curves.


Figure 2 below illustrates the concept of the clear zone.

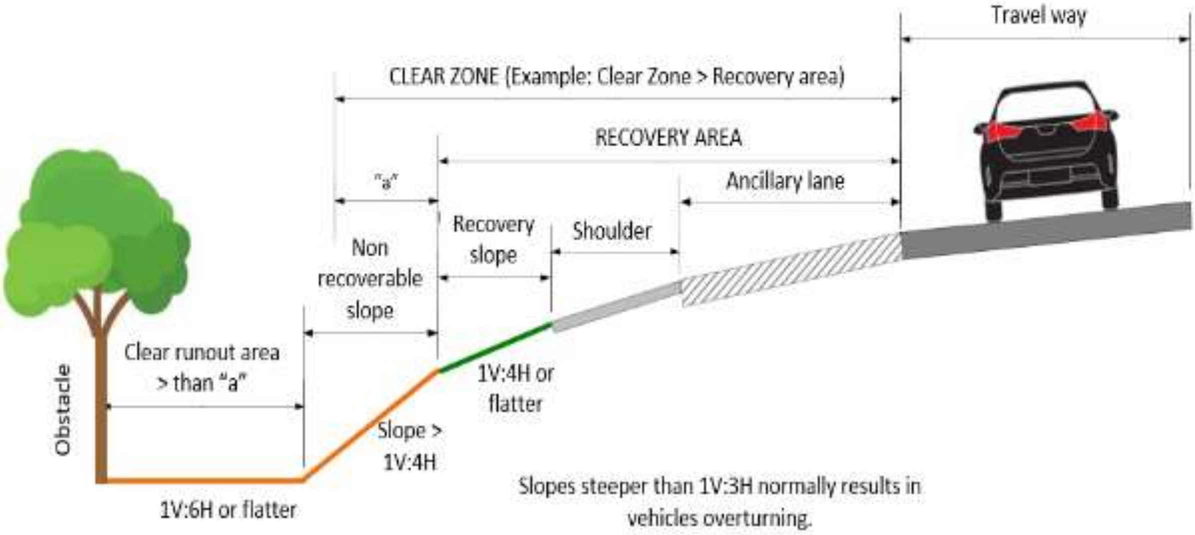


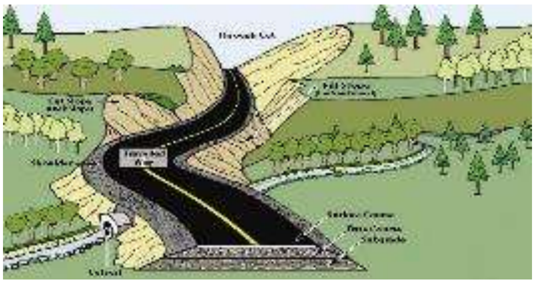

Figure 2: Roadside Terms Definitions

The appropriate width of a clear zone on a straight segment of road, measured in metres from the edge of the travel lane, as a function of design speed, traffic volume and cut/fill slope geometry is provided in Volume 2. Where side slopes are steeper than 1:3 (i.e. recovery unlikely), designers should consider providing a roadside barrier. Noted that these values apply to cars. A safe roadside design for trucks would require significantly flatter slopes as follows:

**Typical clear zone distance**

- **Urban 5 m;**
- **Minimum horizontal clearance behind curb 0.5 m; and**
- **Rural 10 m.**


- 1:10 is recoverable for trucks;
- 1:6 is traversable for trucks;
- 1:4 cannot be safely traversed by trucks;
- 1:6 is desirable for cars;
- 1:4 is recoverable for cars; and
- ≥ 1:3 recovery less likely, cars may overturn.



For road segments with curvilinear horizontal alignment, these dimensions should be increased on the outside of the curves by a factor that depends on the operating speed, radius and super-elevation.

**The following notes on applying the clear zone to a particular site need to be recognised:**

- The clear zone concept offers verge dimensions that provide an increased safety level for the occupants of errant vehicles that may leave the road. Calculate the recommended minimum clear zone dimensions from the Volume 2: Road Restraint Standards and Requirements Manual;
- The clear zone on a particular section of road will not necessarily be constant as the width may vary depending on road geometry, the presence of embankments, vehicle operating speeds and daily traffic volume. If the road section under study is long, it may contain several curves and steep side slopes at various positions along its length;

**Clear zone on curve:**

**Clear zone curve = clear zone x curve adjustment**

- A schedule of calculated clear zone widths needs to be rounded up to the nearest metre for ease of use (this adds a very small safety factor into a system with many variables);
- Each clear zone width is set out at right angles from the painted edge line or the edge of the road pavement if there is no edge line. All fixed hazards greater than 100 mm in diameter (or

continuous hazards such as concrete-lined drains) that occur within the clear zone need to be identified;

- Clear zones should be applied to rural and urban road design wherever practical. Applying the clear zone concept in well-established urban environments is usually constrained by a lack of space and fixed objects (e.g. utilities and road furniture) located within the verge;
- In both the clear zone and hazloc processes, hazards are assessed individually and may be disregarded for treatment if the risk is low. In practice, a combination of hazards often occurs at close spacing, and the designer needs to assess whether one treatment installation can mitigate a group of hazards;

**Identify all fixed hazards more than 100 mm in diameter or continuous hazards such as concrete-lined drains that lie within the clear zone.**

- Where there is an auxiliary lane adjacent to the through lane, it is appropriate to consider the auxiliary lane width as part of the clear zone required for the through lane. Notwithstanding, the clear zone required for drivers using the auxiliary lane should also be considered; and
- All hazards within the clear zone need to be recorded. For existing roads, digital recording is recommended. The practitioner needs to contemplate any opportunity to provide wider clear zones wherever possible, particularly for high-speed, high-volume roads.

## 2.2 STEP 2: IDENTIFY HAZARDS

Once clear zones are established, it is necessary to identify all roadside hazards within the clear zone and consider high-risk hazards located beyond the clear zone.

A roadside hazard is an object or feature located between the edge of the traffic lane and road reserve boundary or within a median that could cause significant personal or fatal injuries to vehicle occupants when impacted by an errant vehicle.

**A roadside hazard is an object or feature located between the edge of traffic lane and road reserve boundary or within a median that could cause significant personal injury (including fatal injury) to vehicle occupants when impacted by an errant vehicle.**

It is essential to understand that while a safety barrier effectively shields severe hazards, the barrier will invariably be longer and closer to the road than the actual hazard that it may be shielding. The barrier, therefore, will have a greater probability of being impacted, and the number of crashes is likely to increase even though a net road safety gain is realised through the reduced severity of impacts. The

**Identify all fixed hazards more than 100 mm in diameter or continuous hazards such as concrete-lined drains that lie within the clear zone.**

practitioner shall note that a barrier is visible and has a lower probability of being hit than other hazards.

Most traffic signal poles are not frangible and are generally not protected. These poles are designed with the strength to support the necessary traffic signal apparatus/signal heads and road lighting hardware (particularly under wind loading), so the provision of barriers to shield these poles is usually impracticable or would lead to reduced overall safety. Most importantly, traffic signal systems provide significant net road safety benefits, despite their supports being expected to endanger errant vehicles.

As an aid to hazard identification, the types of hazards potentially encountered in roadsides are summarised as a workflow in Figure 3.

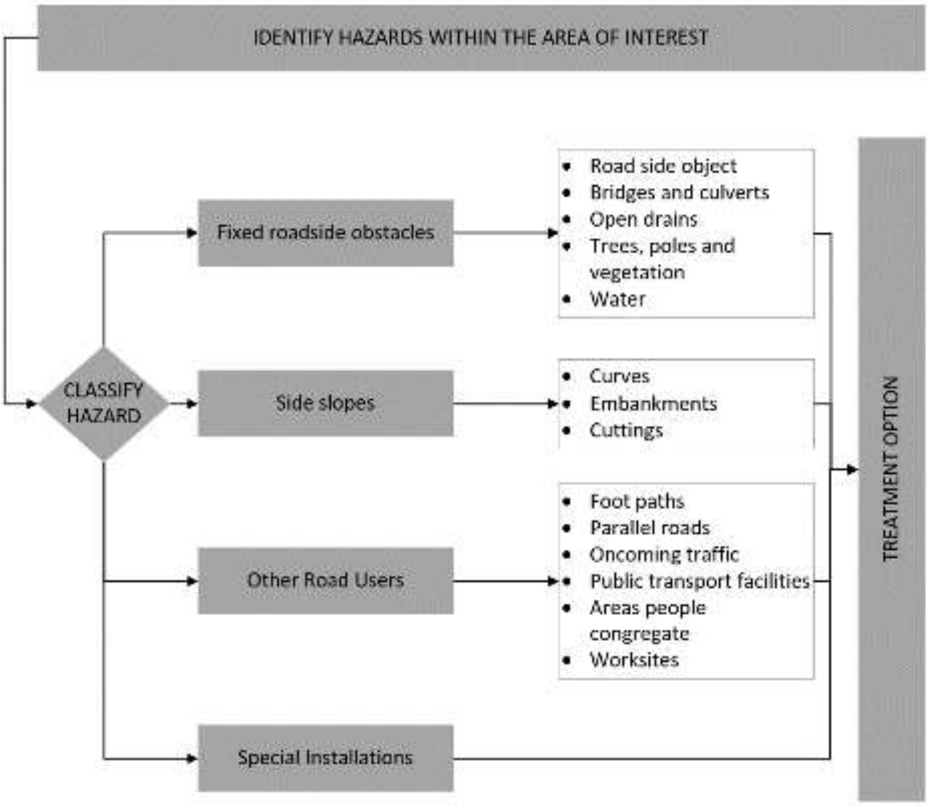



Figure 3: Generalised Identification of Hazards and Classification Workflow

## 2.3 STEP 3: IDENTIFY TREATMENT OPTIONS

Where hazards exist within the area of interest (or outside the clear zone in the case of severe consequence hazards), treatment options should be identified to assess their effect on reducing the risk associated with the hazard, as illustrated in Figure 4.

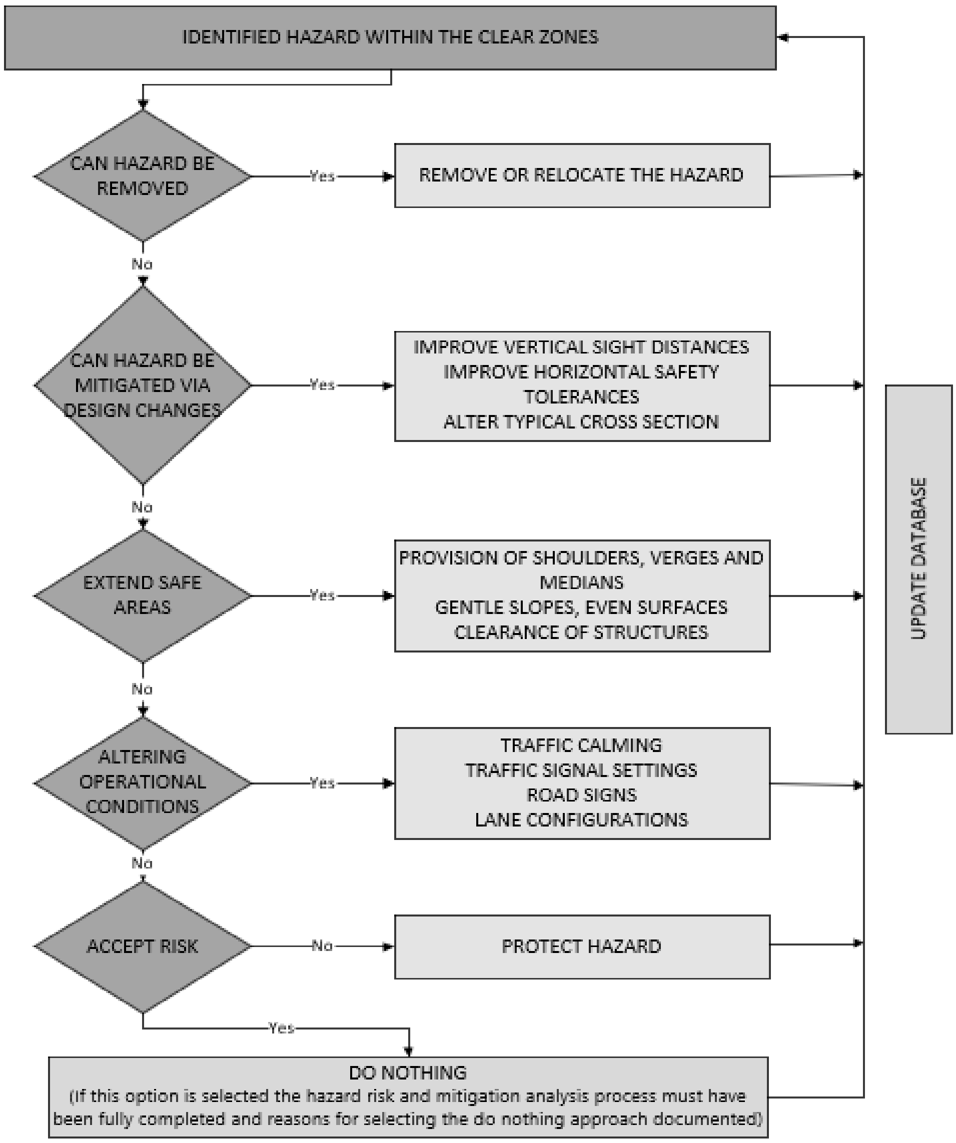



Figure 4: Simplified Hazard Treatment Option Workflow

## 2.4 STEP 4: EVALUATE AND SELECT TREATMENT OPTIONS (INCLUDING RISK ASSESSMENT)

### 2.4.1 Safe System Approach

Adopting a safe system approach to road safety recognises that humans as road users are fallible, they will continue to make mistakes, and momentary errors should not result in death or severe injury. Therefore, the road corridor (and vehicles) should be designed with a primary focus on reducing the incidence and severity of crashes when they inevitably occur. Every endeavour should be made to create a safe system. A safe system is a holistic approach that requires:

- Designing, constructing and maintaining a road system (roads, vehicles and operating requirements) so that forces on the human body generated in crashes are generally less than those resulting in fatal or debilitating injury;
- Improving roads and roadsides to reduce the risk of crashes and minimise harm – measures for higher-speed roads, including dividing traffic, designing 'forgiving' roadsides and providing clear driver guidance. Speed management supplemented by road and roadside treatments are crucial for limiting crashes in areas with large numbers of vulnerable road users or substantial collision risk; and
- Managing speeds and considering the array of various risks inherent to different parts of the road system.

Safer road user behaviour, speeds, roads and vehicles are the four key elements that make up a safe system. In relation to speed, the Australian Transport Council (2006) reported that the chances of surviving a crash decrease markedly above certain speeds, depending on the type of crash. Speed threshold values for different accident types are as follows:

- Pedestrian struck by vehicle: 20 to 30 km/h;
- Motorcyclist struck by a vehicle (or falling off): 20 to 30 km/h;
- Side-impact vehicle striking a pole or tree: 30 to 40 km/h;
- Side-impact vehicle to vehicle crash: 50 km/h; and
- Head-on vehicle to vehicle (equal mass) crash: 70 km/h.

### 2.4.2 Contribution of Roadside Design to Road Safety

A vital component of the safe system approach is safer road reserves. A large proportion of crashes on road networks, particularly in rural areas, involve run-off-road crashes. The design of the roadside and ancillary features can either adversely affect road safety or contribute to a safer environment for all road users. The primary road environment safety objective is to reduce crashes and casualties. This can be achieved by improving the road environment (together with traffic management).

Rural road verges accommodate various drainage features and infrastructure such as open drains, traffic signs (and their supports) and road safety barriers, while urban roads usually accommodate walkways, public utilities, landscaping and other facilities. All roadside features and infrastructure should be designed to support the safe systems approach, especially during initial design (greenfield), minimising the roadside risk for errant drivers. Road design practitioners are compelled to significantly contribute to crash reduction by applying best practices to roadside design.

### 2.4.3 Assessment of the Hazard and Treatment Consideration

Once a hazard has been identified, the hazard is assessed for severity and treatment options are devised. This can include a quantitative assessment and a qualitative assessment. A qualitative assessment is based on the suitability of the treatment option taking social, environmental and other factors into consideration, while a qualitative assessment of treatment options needs to evaluate efficiency ad effectiveness.

**Treatment options should include those that reduce the frequency of impacts with any object or reduce the consequences when an impact occurs.**

**Some possible treatment options, may be an alternative to the installation of road safety barriers.**

An evaluation matrix considering risk, technical and other parameters can be compiled. Issues that need to be considered include:

- Performance capability;
- Risk reduction;
- Cost;
- Time to implement (including lead times);
- Constructability; and
- Ongoing maintenance and repair.

The implementation of RRS may impact the natural or built environment, and practitioners must ensure compliance with the legislated environmental authorisation processes. RRS may have an aesthetic impact, and designers need to be sensitive to the visual impact on the receiving environment (e.g. stone masonry may be used along historical mountain passes; however, containment can not be guaranteed).

Stone Masonry barrier on Chapmans Peak Drive

All viable treatment options should be considered when assessing hazard management. Treatment options should include reducing the frequency of impacts with any object or reducing the consequences, should an impact occur.

The evaluation process may result in several viable treatment options from which one or more may be chosen. Alternatives to installing a road safety barrier need to be included in assessing treatment options.

Quantitative methods used for a more detailed investigation of hazards and treatment options include an economic analysis of the crash costs associated with retaining a hazard compared to reducing crash costs and the whole-of-life costs associated with treating the hazard. This benefit-cost (B/C) analysis of roadside hazards and treatments is similar to analyses undertaken for road projects in general.

### 2.4.4 Quantitative Assessment

Volume 2, Annexure A, SA Risk Assessment Procedure provides a methodology for assessing RRS. A quantitative RRS evaluation includes assessing the risk associated with exposed hazards and the computation of the annual cost of crashes. The same method is used to analyse the risk and determine the annual crash costs associated with treatment options (i.e. shielding vehicles from the hazard). This information can then be used with installation, construction and maintenance costs to undertake a B/C analysis.

**A quantitative evaluation includes an assessment of the risk associated with hazards and computation of an annual cost of crashes.**

Having a B/C ratio greater than unity may not justify constructing a roadside-safety treatment. Each project must compete with other network proposals for limited funds under an appropriate budget. The methodology described in TMH 20, Socio-Economic Analysis Of Road Projects, applies to the evaluation of RRS.

Severity indices are related to crash costs to inform B/C analyses to estimate the benefits derived from a specific course of action compared to the cost of implementation. Should the estimated benefits of a specific design exceed the cost of constructing and maintaining that design over a reasonable analysis period, the safer design may be implemented provided that an environmentally justified course of action has been followed.

By selecting one design in favour of another, it is expected that an accrued reduction in future crash costs will be achieved. These include the costs associated with property damage, personal injury and fatalities. In some cases, a given treatment may reduce the total number of crashes by providing a significantly wider roadside recovery area than previously existed. In other instances, the safety treatment may not reduce the total number of crashes but may reduce their collective severity (e.g. by installing a barrier, run-off-road crashes into a hazard may become less severe).

### 2.4.5 Qualitative Assessment

Before a treatment option is selected for prioritisation and implementation, its suitability for the environment and the engineering factors should be considered.

*i. Environmental considerations*

Some environmental issues that require consideration include:

**Treatment options are to be tested for both environmental and engineering requirements.**

- Recognition of unique vegetation (e.g. environmentally sensitive areas or national parks);
- If the clearing of trees within the clear zone is unacceptable on environmental grounds, alternative treatment options will have to be considered;
- The retention of watercourses in their natural state adjacent to the road;
- Land use and activities along the road; and
- Aesthetic degradation.

*ii. Engineering considerations*

The engineering factors that require consideration include:

- Current traffic volumes as well as traffic growth;
- Pedestrian and cyclist traffic (with special attention to children);
- Vehicle mix, including motorcyclists;
- Crash history;
- Geometric characteristics;
- Whether the road is used as a school bus route;
- Access requirements; and
- Whether the road is used as a freight route.

<u>RRS influence the surrounding communities, and public participation is an essential input in the selection, planning and design of the RRS system.</u>

Sites with a significant crash history may indicate that an RRS is required or an existing RRS needs upgrading and should be considered in the overall RRS planning and design process. The verges along school bus routes or freight routes require special attention, as they may generate high volumes of young pedestrians who require a higher level of protection (e.g. physical separation from the road or shielding).

### 2.4.6 Hazard Design Considerations

To assess the risk posed by a hazard, the process typically involves the following three steps:

- Calculate the frequency of errant vehicle crashes;
- Consider the severity of the crash with the hazard; and
- Objectively compare the risk of retaining an unprotected hazard with the risk of implementing a particular treatment option.

Various models are available to estimate a road user's exposure to risk hazards posed by a clear zone. These models are all based on typical crash rates modified by *modification factors*, thereby calculating a complication index for a road segment. A Risk Assessment Procedure, based on the NetSafe 3 methodology, was developed for South African conditions (RAPSA). See Volume 2, Annexure A.

Design elements that require special attention during the design process include but are not limited to:

- Vertical gradients
  The presence of a downgrade can affect the encroachment frequency. The run-off-road frequency is adjusted by a grade adjustment factor that allows for the increased likelihood of leaving the roadway when travelling downhill;
- Horizontal curves
  The run-off-road frequency is further modified by a curve adjustment factor that allows for the increased likelihood of a vehicle leaving the roadway when travelling on horizontal curves. The curve adjustment factors refer to the inside and outside of the curve in the direction of travel;
- Passing and climbing lanes;
- Lane width;
- Paved shoulders;
- Recovery area;
- Median recovery area;
- Barrier lines;
- Road lighting;
- Parking;
- Lane merge zones;

Well maintained horizontal curve

Pedestrain Crossings & Paved Walkways

Raised Pedestrain Crossing

- Level crossings;
- Bus stops;
- Pedestrian crossings;
- Driveways; and
- Intersections and junctions.

Typical Rural Bus Stop

## 2.5 STEP 5: TREATMENT OPTIONS

### 2.5.1 Essential Considerations

A certain amount of risk is associated with all treatment options to shield hazards. It is, therefore, critical that the comparative risk of treatment by restraint should be assessed against the risks associated with an untreated hazard. Research and experience have confirmed that a clear, unimpeded roadside allows drivers of errant vehicles to reduce speed, recover control of the vehicle and lessen the severity of roadside encroachment consequences. Determining the appropriate treatment option for specific hazardous objects requires five basic considerations:

**A clear, unimpeded roadside is ideal as it allows drivers of errant vehicles to reduce speed, recover control and lessen the severity of encroachment roadside consequences.**

- Keep the vehicles on the road;
- Hazard removal;
- Hazard relocation;
- Modify (treat) the roadside hazards; and
- Shield the hazard.

### 2.5.2 The Efficiency of Treatment Options

An effectiveness rating of the various types of treatment to reduce the risk associated with specific types of crashes is indicated in the table below. In addition, the type of hazard reduction is also listed against the various physical interventions.

TABLE 1: EFFECTIVENESS OF TREATMENT OPTIONS

| Treatment | Type of hazard reduction | Effectiveness of treatment by crash type | | | | |
|---|---|---|---|---|---|---|
| | | Off path, on straight | Off path, on curve | Out of control on curve | Cross-median head on | Impact with hazard |
| Duplicate carriageway | Reduce inherent hazard | | | | Very high | Medium |
| Widen median | Reduce inherent hazard | | | | High | |
| Seal shoulder | Reduce inherent hazard | High | High | High | High | |
| Widen or replace bridge or culvert | Reduce inherent hazard | Medium | Medium | Medium | Medium | |
| Improve alignment | Reduce inherent hazard | Medium | Medium | | Medium | Medium |
| Remove roadside hazards | Prevent an incident | Very high | Very high | | | |
| Widen shoulder | Prevent an incident | Medium | Medium | Medium | Medium | |
| Provide overtaking lane | Prevent an incident | Medium | Medium | | Medium | |
| Advisory speed sign | Prevent an incident | | Medium | Medium | | Low |
| Provide linemarking and guideposts | Prevent an incident | Low | Medium | Low | Medium | Low |
| Install road safety barriers on median | Provide protection system | Low | Low | Low | Very high | Very high |
| Install verge road safety barriers along length of road | Provide protection system | Medium | Medium | | | Very high |
| Resurface road | Reduce inherent hazard | Low | Medium | Medium | | Medium |

Note: The effectiveness of other countermeasures for non-intersection crash types is provided in the *Guide to Road Safety – Part 8: Treatment of Crash Locations* (Austroads 2009a).

Source: Based on RTA (2008).

### 2.5.3 Design Vehicle (See EN 1317 and Volume 2 item 2.1)

Testing methods for RRS infrastructure, i.e. safety barriers, terminals, transitions and crash cushions, were designed to test specific vehicle classes for a distinct number of crash configurations (position and impact angle) and impact speeds. These tests are not necessarily representative of the extreme or even the most common situations that may occur on the road network. These tests are defined in terms of containment levels based on a specific vehicle class and mass, speed and impact angle. No test facilities are available in South Africa and European norms have been recommended for use in South Africs. It is currently not practical to specify a customised set of design conditions (i.e. a design vehicle colliding at a user-defined speed impact angle) to be imposed upon a specific RRS design.

### 2.5.4 Treatment for Protection from Trees

**A tree with a diameter > 100 mm will require consideration.**

Trees feature prominently as impacted hazards in run-off-road crashes, resulting in many fatalities. Trees are particularly hazardous when located within and close to curves.

Trees with a diameter greater than 100 mm and located within the clear zone pose a particular hazard to motorists. For protection from trees, only two possible treatment options exist:

- Tree removal; and
- Installation of road safety barriers.

### 2.5.5 Treatment on Steep Downgrades

On steep downgrades, treatment options may include:

- A gravity safety ramp;
- An arrestor bed (See the American Association of State Highway and Transportation Officials (AASHTO) Policy on Geometric Design of Highways and Streets);
- Emergency escape ramps;
- A dragnet; and
- A combination of the above systems.

### 2.5.6 Treatment of Medians

**Median barriers should only be installed where the consequences in their absence are more severe than the consequences of striking them.**

Designers should note that guidelines for median design and barriers to protect drivers from severe cross-median crashes may vary between road authorities. Therefore, designers should refer to relevant road authority policies and guidelines. RRS should promote a uniform approach across the road network.

Most of the principles that govern longitudinal barriers also apply to median barriers. The overriding warrant for median barrier installation is that they should only be installed if the resulting consequences, if they did not exist, are more severe than the consequences of striking them. The incidence of illegal cross-median movements is excessive, so median barriers may be justified.

1) *Median Road-Safety-Barrier Selection*

When considering median road safety barriers, the practitioner needs to consider the following:

- Impact severity at high speed, which is a measure of the likely damage to vehicles and injury to occupants;
- Cost per crash, including human and overall incident economic cost, based on information typically collected and converted to monetary terms by the relevant road authority;
- Width required for system hardware, thus influencing the minimum median width required;
- Sight distance requirements and aesthetics, i.e. the effect that the barrier will have on driver sight distance and the visual impact of the barrier – this is especially important for the fast lane on the inside of horizontal curves;
- Drainage, including the effects on expelling surface water run-off;
- Integration of barrier and other infrastructure elements such and lighting poles; and
- Requirements for barrier terminal treatments.

2) *Minimum Median Width*

The South African National Roads Agency SOC Ltd (SANRAL) applies the following principles regarding median barrier installation:

**Median > 15 m: no barriers required.**

- For median widths of 15 m or greater, median barriers are generally not required;
- For median widths of 10 m and less with ADT > 30000 vpd – install a barrier; and
- Install a barrier for median widths of 8 m and less with ADT < 30000 vpd.

Typical 10 m median, ADT > 30000

3) *Terrain Effects*

**Kerbs are not recommended where median barriers are present.**

For a median barrier to be effective, it is essential that the vehicle has all its wheels on the ground at the time of impact and that its suspension system is neither compressed nor extended. Kerbs and sloped medians are of particular concern since a vehicle traversing one of these features before impact may go over or under the barrier or snag on its support posts. Kerbs may create a hazard specifically on roads with speeds above 80 km/h and are not recommended where median barriers are present (see SANRAL standards).

Medians should be relatively flat (slopes of 1:10 or less) and free of rigid objects. Where this is not the case, carefully considered placement of the median barrier is needed:

- The slopes and ditch sections should first be checked in depressed medians or medians with a ‘ditch section’ to determine whether a roadside barrier is warranted. If only one slope requires shielding, a median barrier should be placed near the shoulder of the adjacent travelled way;
- **If neither slope requires shielding, but both are steeper than 1:10**, a median barrier should be placed on the side with the steeper slope, when warranted;
- **If both slopes are relatively flat**, then a median barrier may be placed at or near the median's centre if vehicle override is not likely;
- For **stepped medians** that separate travelled ways with significant elevation differences, a median barrier should be placed near the shoulder adjacent to each travelled way if the embankment slope is steeper than 1:10. If the cross-slope is flatter than 1:10, a barrier could be placed at or near the median's centre;
- Placement criteria are not clearly defined **for raised medians or median berms**. Research suggests that the cross-section of a median berm itself, if high and wide enough, can redirect vehicles impacting at relatively shallow angles;
- Additional width will be required where a median barrier **is located within a curve**, and the barrier impedes sight distance to objects on the road or the brake lights of vehicles preparing to stop in the median lane (e.g. due to an incident such as frequent congestion or a crash). Some authorities may consider additional clearance desirable because of the likelihood of vehicles shying away from a barrier; and
- An important consideration concerning the clearance to median barriers, particularly the more rigid systems, is **accessibility for maintenance** crews undertaking repairs and the occupational health and safety issues surrounding such activities.

Generally, if the cross-section is inadequate for redirecting errant vehicles, <u>a semi-rigid barrier should be placed at the cross-section's apex</u>. If the slopes are not traversable, roadside barriers should be used near the shoulder adjacent to each travelled way.

*4) Flare Rate of the Barrier*

**Median barrier flare = Flare rates for roadside barrier.**

If a median barrier has to be flared at a rigid object in the median, the flare rates for conventional roadside barriers should apply.

*5) Treatment of Rigid Objects in the Median*

A particular case may result in circumstances where a median barrier is not warranted but rigid object warrants shielding. Typical examples are bridge piers, overhead sign support structures and high mast lighting installations. If shielding is necessary for one direction of travel only, or if the object is in a depressed median and shielding for either or both directions of travel is necessary, the same criteria for roadside barriers should be used.

If shielding for both directions of travel is necessary, and if the median side slopes are steeper than 1:10, the designer may investigate the possibility of a crash cushion (or an earth berm) to shield the object. The use of barriers with crash cushions or earth berms should also be considered to shield the barrier ends.

*6) Openings in the Median as a Result of Underpasses*

The cost implications of providing underpasses sometimes require an opening in the median. In such instances, the use of transverse barriers (or concrete balustrades) shielded by crash cushions should be considered.

*7) Encroachment onto Opposing Carriageway*

The minimum median width required to accommodate the anticipated deflection of a safety barrier depends on the barrier's constructed width and the clearance required between the barrier and the edge of the travelled way. The clearance specified will depend on the dynamic deflection expected under impact at the specified containment level or a nominal minimum clearance necessary for drivers to feel comfortable travelling adjacent to the barrier. In general, it can be expected that concrete barriers will undergo virtually no dynamic deflection. Steel barriers and wire rope safety barriers will deflect to varying degrees depending on the system used (related to a combination of factors such as post spacing, rail stiffness, means of connection, etc.).

A vehicle colliding with a wire rope road safety barrier (WRSB) may encroach beyond the oncoming barrier line or cause barrier wires or posts to encroach beyond this line. While experience shows that the WRSB reduces the consequences of a head-on collision by reducing the crash-causing vehicle's speed, it is desirable to provide a sufficiently wide median to limit encroachment into opposing traffic.

Example of vehicle encroach with wired

The probability of a collision due to encroachment after impact with a WRSB in a narrow median is related to the probability of a vehicle being adjacent to the impact site during this short period and the designed deflection being exceeded.

Issues that need to be resolved in considering median treatments include:

- Incident clearance time;
- Width of the median (existing or proposed);
- Provision of future lanes;
- Sight distance;
- Median breaks influence the median width;
- Road safety barriers;
- Environmental impacts;
- Construction and maintenance;
- Delineation;
- Road user issues (e.g. pedestrians crossing dual carriageway roads); and
- Cost.

SANRAL has, through ongoing experience, proposed a so-called avoidance manoeuvre width applicable to curves to the right on dual carriageways. This has been incorporated, in draft format, into SANRAL's typical cross-section details updated periodically.

*8) Median Barriers as Access Management Treatment*

The installation of median barriers has the additional benefit of restricting U-turn manoeuvres and preventing access to the dual carriageway road from illegal accesses. The enforcement of Access Management Plans through median barriers could be considered in the qualitative assessment of RRS.

### 2.5.7 Treatment of Verges

Issues that need to be resolved in considering verge treatments include:

- Incident clearance times;
- Width of verge;
- Cut, fill slopes;
- Provision for future lanes;
- Sight distance (as affected by HA, VA and cross fall);
- Intersections;
- Footways;
- Road safety barriers;
- Environmental impacts;
- Construction and maintenance provisions;
- Delineation;
- Provision for drainage systems;
- Emergency access;
- Road user issues (e.g. pedestrian and cyclist facilities);
- Cost; and
- Public transport lay-bys.

### 2.5.8 Treatment of Side Drains (Open Drains)

Deep, unprotected drains should not be installed at the base of cut faces. Effective redirection of errant vehicles requires a flat, even surface approaching the batter.

**Open drains are a hazard for errant vehicles that leave the road – unless they are of a suitable shape.**

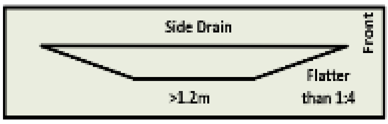
Open drains are present on the majority of rural roadsides and some urban freeways. While open drains constructed close to the road may be the most efficient way of removing sheet-flow water, they are a hazard for errant vehicles that leave the road unless they are of a suitable shape.

Most typical drains can be classified as having either abrupt or gradual slope changes. Abrupt slope change designs include V-drains, drains with a rounded invert width of less than 2.4 m, and trapezoidal drains with widths of less than 1.2 m.

Typical V-Drain

Vehicles leaving the roadway and encroaching into a drain generally face three hazard areas:

- Drain front slope – if the front slope is 1:4 or steeper, most vehicles entering the ditch will be unable to stop and can be expected to reach the bottom;




- Drain bottom – abrupt slope changes at the bottom of the drain can cause errant vehicles to roll or stop abruptly and increase the severity of the impact; and
- Drain back slope – vehicles travelling through the ditch bottom or becoming airborne from the front slope can collide with the back slope.

Open drain sections that fall outside the design requirements are considered non-traversable and should therefore be:

- Reshaped;
- Converted to a closed system (box or pipe culvert);
- Located beyond the area of interest; and
- Shielded with a road safety barrier where appropriate.

If the drain bottom and slopes are free of fixed objects, drain sections with dimensions considered less safe may be acceptable for projects where better treatment is impracticable or uneconomical because of factors such as:

- A restrictive right-of-way;
- Rugged terrain;
- Resurfacing, restoration or rehabilitation projects where it is not feasible to provide a compliant shape; and
- Low-volume, low-speed roadways.

**No objects allowed in drain with high-severity attributes (bottom or side slopes).**

Open drains of both the abrupt and gradual slope designs can funnel a vehicle along the drain bottom, increasing the probability of impact with an object with high-severity attributes. Such objects are present on the bottom or side slopes of the drain, where the road reserve has become more congested over time. For this reason, and aside from adverse water flow effects, such objects should not be located within drains

Back slopes typically occur when roadways are constructed by cutting the existing terrain away to develop the roadbed. If the slope between the roadway and the base of the back slope is 1:3 or flatter, and the back slope is obstacle-free, then the back slope may not be a significant hazard regardless of its distance from the roadway. Back slopes that cannot provide a relatively smooth redirection or cause vehicle snagging should be located outside the clear zone or shielded. This usually includes rough-sided rock cuttings where the untreated face can cause excessive vehicle snagging.

### 2.5.9 Treatment of Drainage Inlet and Outlet Structures

The ends of culverts that cross under the road or are located parallel to the road constitute hazards within the clear zone. Road design should eliminate all non-essential drainage features from the clear zone. Where drainage features are unavoidably located within the clear zone, they should be designed as follows:

- Drains parallel to the road (e.g. under a driveway or side road) – traversable culvert end treatments should be installed wherever a culvert exists parallel to the road and within the area of interest. (Grid inlets as an alternative);

Dangerous deep open drain parallel to road

- Perpendicular to the road (headwall treatment) – culverts aligned across and beneath the road should be designed to either be traversable or present a minor obstruction to an errant vehicle where the fill batter is gentle enough to be driveable. If not, the inlet or outlet structure should be shielded with an appropriate road safety barrier if the slope is not driveable. Alternatively, the culvert barrels can be extended to a location further from the travelled way (e.g. at the clear zone distance) where the headwall ends are less likely to be impacted by errant vehicles. This option may not be preferred.

Inlet structures within clear zone

**Road design should aim to eliminate all non-essential drainage features, for example 'exposed wing walls'.**

Traditionally, culverts in South Africa have been designed with concrete headwalls and wing walls that often result in a potential roadside hazard or require shielding with a road safety barrier. The options to remove or reduce the hazard caused by these obstacles are (AASHTO 2006):

- Design the culvert end to be traversable;
- Extend the culvert to a point beyond the appropriate clear zone;
- Shield the culvert with a road safety barrier; and/or
- Delineate the culvert if the previous options are not cost-effective or practicable.

Drainage structure close to road

If a front slope (embankment or drain) is traversable, the preferred option is always to extend (or shorten) the culvert to intercept the roadway embankment and match the inlet or outlet slope to the embankment slope. For minor culverts, no other treatment is required. A minor culvert may be defined as a single pipe with a diameter of 900 mm or less or multiple pipes with a diameter of 750 mm or less.

Matching minor culvert ends to embankment slopes is also desirable because, when constructed properly, it:

- Results in a smaller obstacle for an errant vehicle;
- Reduces erosion problems; and
- Simplifies mowing operations.

Safety treatment for cross-drainage culverts will prevent erant vehicles from getting damaged by the structures

If a front slope is not traversable, it may not be appropriate to provide a traversable end treatment, and an evaluation of alternative treatments must be undertaken (e.g. improve embankment, shield with road safety barrier).

As a significant percentage of errant traffic may travel beyond the clear zone, a culvert and an extended location may still be a hazard. Therefore, extending culverts beyond the clear zone distance still requires providing traversable ends, particularly on high-speed roads, to prevent discontinuities along an otherwise traversable slope. However, if the land immediately beyond the clear zone contains other hazards that cannot be removed for practical or environmental reasons, it may be acceptable to provide a non-traversable end treatment at or beyond the clear zone distance.

Example of a dangerous drainage structure vs safe structure, at minor road junctions

Bar grates, single culverts, and end treatments wider than 1.0 m can be traversable for passenger-sized vehicles. Full-scale crash tests had shown (AASHTO 2006) that cars can cross grated culvert end treatments on slopes as steep as 1:3, at speeds as low as 30 km/h or as high as 100 km/h, when steel pipes spaced 750 mm apart are used across the opening. Although this treatment does not significantly change the culvert's hydraulic performance, due consideration should be given during the design process to the likely accumulation of debris and the level of maintenance required. It may be appropriate not to treat the end of a culvert and only provide adequate delineation.

All things being equal, the provision of barriers on low-volume roads should not result in a higher risk to road traffic than if barriers were not provided. A B/C analysis may show that barriers are not warranted on low-volume roads, which will occur if the benefits of installing a barrier (potential reduction in crash costs) do not outweigh the barrier installation costs.

### 2.5.10 Treatment of Fill Slopes

*Geometric Design Guidelines* guide fill slopes' design (also referred to as batters). Batters should be constructed to an acceptable slope and be free of features that prevent a driver from regaining control of an errant vehicle (i.e. drivers should negotiate the slope safely). A road safety barrier should be considered if the batter slope is severe enough to cause an errant vehicle to overturn.

**Side slopes flatter than 1:4 if possible.**

The concepts of *recoverable*, *non-recoverable* and *critical fill* batter slopes refer to the likelihood of a vehicle overturning on various slopes. After running off the road onto a recoverable batter slope, a driver can usually regain control of the car and return to the road or stop safely. On a non-recoverable slope, the driver is unlikely to return to the road but will stop safely at the bottom of the slope. A critical slope will be of such geometry that will probably cause the vehicle to overturn.

### 2.5.11 Treatment of Rock Face Cuttings

**Cuttings and rock faces should be designed to provide a smooth face.**

Cuttings through rock are expensive to construct. Economic and environmental constraints often result in cuttings being as narrow as possible, preventing a clear, neat flat verge beside the road. Therefore, cuttings and rock faces should be designed to provide a smooth face that acts as a rigid barrier, allowing errant vehicles to slide along and stop gradually. Uneven batter surfaces may present a serious hazard to vehicles that happen to run off the road, often resulting in snagging and rolling. Where a smooth surface face and approach surface cannot be provided, installing a barrier to prevent vehicles from colliding with an uneven rock surface may be appropriate.


Example of smooth rock faces

There are no guidelines available for the acceptable roughness of rock faces. However, the degree of roughness that will result in an effective rigid barrier is very low.

### 2.5.12 Roadway Improvements Treatment Options

Road design and road network management can contribute to improved road safety, including the following:

*1) Design of horizontal curves*

- Aim to keep vehicles on the road, thereby preventing collisions with roadside hazards;

- Provide adequate super-elevation on curves;
- Design clear pavement markings. This is one of the most cost-effective treatments applied to curves. Centre lines and edge lines effectively direct drivers around curves and prevent run-off-road crashes. Reflectivity at night is enhanced by reflective beads;
- Provide audio-tactile edge lines and road markers on the shoulders to warn drivers when they stray near the edge of the travelled path; and
- Provide high visibility warning signs to inform drivers of approaching curves.

*2) Traffic Calming to Reduce Speed*

The application of traffic calming to reduce speed is generally intended for urban residential and collector streets where the hazards are close to the roadway, and it is not economically feasible to remove, relocate or shield the poles and other road furniture. Traffic-calming devices on arterial roads are generally not appropriate because arterial roads are designed for large traffic flows and provide high service and comfort for vehicle occupants, including bus passengers. Implementing traffic-calming measures to achieve lower speeds at high-risk locations can reduce crash severity by decreasing the energy at impact. Generally, lower speeds may also reduce the frequency of crashes. Physical works are generally required to effectively reduce vehicle speeds. Simply reducing the speed limit is ineffective, especially if speed compliance is already low.

**Lower speeds at high-risk locations reduce the severity and frequency of crashes.**

**However, traffic calming needs to be designed as an area-wide strategy – speed reduction may cause traffic to divert to other routes, resulting in an increase of crashes on the alternative routes.**

Traffic calming needs to be designed as an area-wide strategy by reducing speed and specific key segments in an urban street network. The speed reduction will force the regular traffic community to divert to other routes, merely shifting the risk of crashes on these alternative routes.

*3) Road Re-Alignment*

Road re-alignment to reduce the risk of crashes is generally only feasible in conjunction with a major road upgrade programme, including a range of measures to reduce the risk of crashes. Such readjustment opportunities are not common and entail multi-faced considerations, including (sometimes) land acquisition processes.

*4) Road Geometry Changes*

Merging lanes within a horizontal curve

The relocation of merge lanes to an area with fewer roadside hazards may be possible where the merge is entirely defined by line marking. Road geometry augmentation involving pavement and kerb changes should include measures to reduce the risk of crashes into roadside poles and other road furniture.

*5) Delineation Improvements*

Delineation of the travelled path with guideposts, line marking and signposting plays an important role in keeping vehicles in the intended lane but cannot be relied on to prevent run-off-road collisions with roadside hazards.

#### 2.5.12.1 Treatment of Watercourses, Canals and Other Bodies of Water


Bodies of water can be a fatal hazard for road users and should be considered for mitigation, particularly when located within the clear zone or within reach of the errant vehicle.

When considering potential water hazards, road designers should visualise the paths that errant vehicles are likely to take in reaching the water. If the water hazard is substantial and the likelihood of errant vehicles reaching the water is high, careful consideration for RRS is needed, as water bodies are mostly immovable.

## 2.5.13 Treatment of Minor Roadside Hazards

**Roadside furniture and minor roadside obstacles pose a serious risk to errant vehicles. Such objects should be located outside the area of the clear zone where possible.**

Minor roadside obstacles such as fences, fire hydrants, mailboxes and other roadside hazards can pose a serious risk if an errant vehicle strikes the object. Objects containing horizontal rails capable of spearing vehicles (such as post-and-rail fences) can be particularly hazardous. Such objects should be located outside the area of interest or clear zone or in such a way that an impact with the object should not result in a serious crash. Where this is not practicable, objects located close to the road must be designed to minimise risk to road users, often requiring them to be frangible.

## 2.5.14 Treatment of Roadside Furniture

Road sign behind barrier

Traffic signal poles can pose a hazard for any errant vehicles. They are often located close to the travelled path at intersections, leading to a higher risk of impact, although some measures can minimise this risk. Such measures include not locating a traffic signal pole on the outside of a curve, setting poles as far back from the travelled path edge as practicable, minimising the number of poles and installing joint-use poles wherever practicable. Provision of high skid resistance at intersections can also reduce the risk of a vehicle losing control at an intersection and skidding into traffic signal poles or other roadside hazards.

Example of protected gangtry

Small road signs are usually supported by small diameter and thin-walled metal conduits that are frangible under vehicle impact. However, larger signs require substantial supports and should either be provided with frangible mechanisms at the base of the supports (e.g. weakened timber or slip-bases with hinge points just below the sign) or shielded by a road safety barrier or crash attenuator. Frangible bases are often not suitable in urban areas, in which case the support should be located as far as possible from the travelled way or shielded.

### 2.5.15 Treatment of Poles

*1) General*

**Avoid placing poles within clear zone where possible.**

The hazard presented by a roadside pole depends on its location, type of construction, and consequences of an errant vehicle hitting the pole. Poles in road reserves to reticulate electricity are problematic because they are generally costly to remove and replace with an underground supply. However, this option should be considered in appropriate situations.

Poles are a common road furniture item used to support signs (regulatory, warning, guidance and informative), road lighting and various devices. In line with the preferred treatment for roadside hazards (i.e. removal), the practitioner should aim to minimise the number of poles in the area of interest.


Protected Street Lights

Signs should be erected well before a hazard so that speed-dependant sight distance is not compromised. Longitudinally, signs should be located to provide enough warning for a driver to decide and respond as necessary. It is also crucial that signs are spaced far enough apart longitudinally that drivers can process the information before encountering another sign. If these requirements are not satisfied, drivers may react abruptly and lose control of their vehicles. (Position of road signs specified in SARTSM)

*2) Avoid Placing Poles Close to the Roadway Group Options According to Your Approach: Remove, Relocate, Treat, Protect*

Any roadway improvement that involves the reconstruction of utility services should use this opportunity to avoid the placement of poles close to the roadway. This proactive approach will avoid problems rather than result in one having to rectify them in future.

*3) Pole Removal*

Removing a single pole or a small group of poles may lead to crashes migrating to the next pole encountered on tangents to curves, especially where there is a crash history. When considering removing a pole with a crash history, it is essential to understand why vehicles are leaving the road and consider keeping vehicles on the road.

*4) Install Cables underground*

The most effective option for treating hazardous poles is to relocate utility services to underground ducts, thereby removing the poles.

*5) Rationalisation of Pole Functions*

It may be possible to rationalise the number of poles along a road corridor by combining separate functions and services onto common poles. For example, the same poles may support road lighting and large signage (SARTSM, which excludes signal posts). Likewise, power cables, telecommunication services and street lights can share common poles.

*6) Reducing the Numbers of Poles by Increasing Spacing*

Increased pole spacing increases the possibility for errant vehicles to pass between poles. The effective gaps for vehicles to pass through are dependent on vehicle width and the anticipated exit angles.

If increased pole spacing is used to reduce the roadside risk, designers should check that the poles being removed do, in fact, influence crash frequency or have a high risk of collision. It would be counterproductive to remove poles with no hazard history but leave high-risk poles in place.

*7) Relocation*

Pole relocation needs to target areas where run-off-road crashes are likely. For example, zones on the approach to curves, the outside of curves, near lane merges, lane terminations and adjacent exits from roundabouts and intersections are more likely to pose a higher risk.

*8) Reduce Impact Severity*

The use of frangible poles may effectively reduce the severity of pole-related crashes if pole removal or relocation is not feasible. These poles are designed to collapse or break away on impact, thereby reducing the severity of injuries to the occupants of an impacting vehicle compared to those that would likely occur if the pole were rigid.

*9) Frangible Poles*

The following issues need to be considered when specifying frangible poles to reduce impact severity:

- Removing or relocating the pole should be considered as a preferred solution to specifying frangible poles;

- The area behind the pole should be free of other hazards, and in the case of breakaway poles, a run-out area may be required; and
- There should be limited pedestrian activity in the vicinity of the pole. The damaged pole and any elements that detach under impact should not risk other road users.

**Signposts should be designed to be frangible in the event of impact by an errant vehicle. Damage to a colliding vehicle and risk of injury to occupants upon impact must be minimised.**

Impact-absorbing poles should be favoured over slip-base poles in an environment with closely abutting development, pedestrian and parking activity and a low traffic speed environment.

Signposts should be designed to be frangible in the event of impact by an errant vehicle (i.e. posts designed to fracture, breakaway, give way or bend), such that the damage to a colliding vehicle and risk of injury to the vehicle occupants upon impact is minimised. Small signs are usually supported by posts that deform in a way that causes minimal damage to cars, whereas larger posts and supports (for larger signs) may be provided with mechanisms designed to yield in a controlled manner upon impact.

Aspects to be considered in the selection of pole type and setback from the roadway include:

- Surrounding land use;
- Pedestrian activity;
- Speed limit;
- Whether the road is kerbed or un-kerbed;
- Location (mid-block or at an intersection);
- Whether the pole is to be located behind a road safety barrier; and
- Maintenance crew requirements.

Consideration of the above may result in locating them at the property line (urban and rural) or in an easement/servitude zone (rural).

*10) Slip-Base Poles*

Slip-base poles consist of a standard pole stem mounted on two base plates clamped together with bolts that release on impact, thus allowing the pole stem to break away from its foundation. A disadvantage with slip-base poles is that the dislodged pole may create a secondary incident by falling on bystanders or adjacent vehicles.


Slip-base pole

The decision to use slip-base poles will depend on the space available and the likelihood that a falling pole would cause injury to other users of the road or roadside area. For example, a slip-base pole will usually be inappropriate where pedestrian or cyclist traffic is expected because a falling pole may pose an unacceptable risk to those road users.

**A disadvantage of slip-base poles is that the dislodged pole may create a secondary incident by falling on bystanders or adjacent vehicles.**

Lack of maintenance is a significant problem with slip-base poles. They should be checked regularly to ensure they are free to slide and correct bolt tension. Wind vibration can cause poles to move the assembly and jam the bolts.

*11) Impact-Absorbing Poles*

Impact-absorbing poles remain attached to the base structure and absorb impact energy by progressively deforming and entrapping the impacting vehicle. The deformation of the pole is controlled by a designed weakening of the pole stem.

Impact-absorbing poles have fewer maintenance issues than slip-base poles.

Fibreglass poles are designed to comply with impact-absorbing requirements and are also regularly used in South Africa

### 2.5.16 Road Safety Barriers Most Commonly Used Treatment of Hazards.

The purpose of road-safety-barrier systems is to shield vehicles from striking a hazard. However, it is essential to note that impacting a road safety barrier is in itself a hazard for vehicle occupants, although it is usually a less severe hazard than impacting a rigid object in the road reserve (e.g. pole or tree). Road-safety-barrier systems may increase vehicle impacts because they are longer than the point hazards they shield and closer to the traffic they intend to shield.

**Road-safety-barrier systems may increase the likelihood of vehicle impacts because they are longer than the point hazards and are closer to the traffic.**

Installing a road safety barrier in front of a hazard requires space for dynamic deflection, vehicle roll, system width, sight distance, sufficient length for terminals and a run-out area. Therefore, it is necessary to consider other mitigation options (such as hazard relocation) with insufficient space to install a road safety barrier.

### 2.5.17 Road Safety Barriers on Corners of Intersections

The posts should be weakened when a W-beam road-safety-barrier system (Traditional Guardrail on Wooden Posts) is installed around a slight radius curve. These treatments should be provided with a flat area graded at 1:10 or less and free of fixed hazards. If these criteria cannot be met, a non-weakened barrier is to be installed.

The weakened W-beam is more critical at higher-speed locations (i.e. > 80 km/h) because of the dynamic deflection and the barrier's working width.

### 2.5.18 Treatment at Railway Level Crossings

Requirements for barriers at railway level crossings are provided in by SANS 3000 and fall outside the scope of the SARRSM. Short lengths of a road safety barrier around level crossing equipment may be ineffective because of the short length and may present a greater hazard to road users than the equipment protected by the barrier. Installing level crossing equipment as far from the edge of the travelled way as possible and defining the approaches with enhanced delineation can obviate the road-safety-barrier installation.

Treatment of Railway Level Crossing

## 2.5.19 Vertical Restraint and Vehicle Size Management

Vertical restrictions

Failure to adequately warn drivers of overhead bridges often damages bridge structures when trucks or their load hits the underside of the bridge deck. Several methods are available for communicating vertical restrictions to the driver. The most commonly used height restriction signs often seem to be ineffective. This may be due to several reasons:


- Drivers are not always aware of the height of the vehicle or its load;
- Drivers focus on a complex environment neglecting signs on the bridge deck; or
- Varying truck heights due to different loads.

Notice of a height restriction must be communicated to the driver adequately in advance. Either an alternative abnormal route or an adequate turnaround facility must be provided.

Height control must comply with the SARTSM, but it is sometimes necessary to provide additional advance warning. Warning structures and height gauges include both electronic and physical structures. (Electronic measurement is not currently used in South Africa).

- Example of electronic height measurement system

- Example of physical structures


#### 2.5.19.1 Active Electronic Warning Signs

A range of condition-related signs can benefit the ability of motorists to stay on the road by alerting drivers of hazards (e.g. reduced visibility, strong crosswind) or road surface issues.  Common temporal conditions include:



- Heavy rain;
- Ice and/or snow;
- Fog;
- Water on the road;
- Strong winds;
- Construction activities;
- Crashes; and
- High traffic volumes.


Electronic overhead systems may be used where preventing adverse effects increases the risk of road crashes.  This may be as simple as erecting permanent signs, but more complex systems are also possible.  For example, a wind warning system can contain warning lights and signs activated by local weather station inputs. Similarly, a fog warning system could activate warning signs and lights in response to inputs from a visibility detection device.

Dimensional and manoeuvre restrictions

Instances occur on the road network where the dimensions of the road and road reserve cannot accommodate larger vehicles. It is, therefore, necessary to prevent such vehicles from entering the section of the road with limited dimensions. Drivers should be warned, and the necessary prohibition road traffic signs must be installed in advance of the restriction at a position where the vehicle can select an alternative route or turn around where it is possible and safe to do so.

## 2.6 STEP 6: IMPLEMENTATION OF ROAD RESTRAINT SYSTEMS

The holistic, network-level management of roads, namely planning, design, operation and maintenance, should be precursors to installing RRS. RRS should also form part of the road authorities' asset management systems and are subject to routine verification, inspection and appropriate upgrading of existing infrastructure.

### 2.6.1 Road Reserve Management

#### 2.6.1.1 Introduction

A **road reserve** is a legally described area where facilities such as **roads**, footpaths and associated features may be constructed for public travel. The total area between boundaries is shown on a cadastral plan defined in the Road Traffic Act.

The road reserve boundaries are the outside edges of entire road cross-sections and include grassed verges, utility services and routine maintenance by the road authority.

The misuse of the road reserve for human activity leads to increased friction and conflict, reducing capacity and safety. Informal trading, such as informal traders and providing services other than public transport in the road reserve, must be controlled, especially on higher-order roads.

There is a trend to plan and construct roads as so-called 'complete streets', in which case conflict between vehicles and human activity must be properly addressed and mitigated.

Access Management Plan developed by road authorities play an essential role in managing the road environment.

#### 2.6.1.2 Risk

Any social, economic, business and service activity that has not acquired prior approval by relevant road authorities would create a serious risk for legitimate users in the road reserve. Any physical obstruction in the road reserve is a potential hazard, and its presence must be justified.

#### 2.6.1.3 Design

Any work undertaken within the road reserve, particularly closer to the road edge or even by routine maintenance contractor(s), should be handled by trained staff who clearly understand the dynamics of the environment.

Traffic accommodation should be the first step taken to ensure workers and motor vehicles using the road are channelled and arranged to move safely whenever work is undertaken in the road reserve boundaries. For each traffic accommodation set up, a plan of the traffic accommodation measures must be produced, and the Traffic Safety Officer must inspect and sign off this plan every day before the accommodation measures are opened to traffic. Regular inspections must be made by the Traffic Safety Officer and Route Manager to ensure the measures in place are working correctly (RRM August 2008).

## 2.6.2 Land-Use Management

### 2.6.2.1 Introduction

Integrated pubic transport (Pedestrian, cyclist, bus and traffic

Proper land-use planning is an efficient way of sustainably preventing road safety problems. Integrated transport and land use planning is essential to ensure that the road network provides a framework for spatial planning. Transport authorities should comment on the Spatial Development Framewworks of municipalities to ensure that road master planning and Access Manageent Plans are incorporated in land use planning to protect the functional integrity of the road network. Accessibility and exposure to passing traffic provided by major roads attract a range of land uses such as businesses, shops, schools and residential settlement to the road, leading to haphazard and uncontrolled settlement patterns without a proper hierarchy of supporting roads. Road corridors are often characterised by the following:

- Low order gravel roads that have direct access to mobility routes;
- Shops, businesses and other developments with unauthorized direct access to major roads;
- Residential areas located on one side of the main road, with institutions such as schools, clinics and community halls on the opposite side, resulting in risky pedestrian crossing manoeuvres;
- Dwellings and other building structures that encroach into the road reserves; and
- Herds of livestock grazing in the road resrve and crossing the road without control.

While the functional classification of mobility routes may be high, e.g. a Class R1 principal rural arterial or Class R2 major rural arterial, the users of certain segments along these arterials is not long distance travellers, but includes short distance vehicle, bicycles and pedestrians local travel.

Of particular concern is the location of public facilities such as schools, clinics and social security service (e.g. pension payout) centres. These facilities should not be located along Class 1, 2 or 3 roads but instead along Class 4 collector roads serving a residential community. However, the locations of schools are addressed indirectly under scholar transport policy. Typically, scholar transport is provided only where the walking distance would exceed 4 km, and the demand is more than ten scholars on a route.

Land use permitted along roads may also impact the need for RRS. For example, many instances exist where high volumes of pedestrians are permitted either next to the road itself or the road reserve. The risk of vehicles encroaching into these areas may justify RRS to prevent conflict with pedestrians. Alternatively, pedestrians may have to be constrained to not encroach on vehicle paths.

#### 2.6.2.2 Risk

Undertaking any social, economic or business activity that would affect land use without prior planning that considers all prescriptions of the law and relevant policies, community consultations and finally acquiring approvals from the relevant authorities is a high-level risk that can compromise road safety. Although individual road authorities would have their peculiar policies and guidelines in respect of the land-use management, the SANRAL document titled Policy in Respect of Road Planning and Design adequately delineates guidelines that should be followed to ensure due considerations and processes for road safety within the context of land-use management are incorporated.

#### 2.6.2.3 Design

The initial step in land-use management should be thorough spatial planning to locate trip generators on the road network that were compatible with the technical aspects of the road design and road safety, such as locating pedestrian trip generators on collector roads. While the individual road authorities would have their relevant policies and guidelines to be followed in land-use management, the SANRAL document on Policy in Respect of Road Planning and Design provides a clear procedure in the context of land-use management.

The control of existing land uses that impact road operations and safety through RRS must be considered. Longitudinal barriers can be used to limit access or separate vehicle movements from activities on or next to the road reserve.

### 2.6.3 Road Improvements to Avoid Run-Off-Road Incidents (Keeping Vehicles on the Road)

#### 2.6.3.1 Introduction

The inherent aim of transport (whether) driving, riding or walking is to remain on the road or path and not encroach into spaces with a risk of collision. The leading cause of run-off-road incidents is driver inattention and distraction, where the European Commission adopted the following valuable definitions from Engström et al. (2013):

- Driver inattention: 'inattention occurs when the driver's allocation of resources to activities does not match the demands of activities required for the control of safety margins' (Engström et al., 2013, p. 38);
- Driver distraction: 'where the driver allocates resources to a non-safety-critical activity while the resources allocated to activities critical for safe driving do not match the demands of these activities' (Engström et al., 2013, p. 35); and
- Activities critical for safe driving: 'those activities required for the control of safety margins' (Engström et al., 2013, p. 17).

From literature studies, the following factors were found to contribute to run-off-road crashes commonly:

- Road alignment (both vertically and horizontally): alignment changes increase the likelihood of a run-off-road crash;
- Roadway functional class: on rural roadways, 80.6% of crashes were run-off-road crashes; on urban roadways, 56.2% were run-off-road crashes;
- Speed limit: over half of the crashes involved speeds greater than the posted limit before the roadway departure. Run-off-road crashes made up 81% of crashes that occurred on roadways with posted speed limits of 60 km/h and above, and 69% on roadways with speed limits less than 60 km/h;
- Time of day/lighting: run-off-road crashes made up 74.2% of night-time crashes and 66.5% of crashes in the daytime; and
- Weather conditions: run-off-road crashes made up 75.5% of crashes in adverse weather conditions and 70% in good weather conditions.

#### 2.6.3.2 Risks

The risk of run-off-road crashes was shown to increase where driver distraction and inattention will be high. This can be on rural roads due to fatigue or urban roads due to more things in and around the vehicle that overloads drivers' sensory system and data processing. There is also increased risk on high-speed rural roads (typically two-way two-lane roads), restrictive vertical and horizontal curves, driving at night and in inclement weather.

The extent of risk varies widely, and implementing RRS will depend on design criteria, economic analysis and engineering judgement.

#### 2.6.3.3 Design

The National Co-operative Highway Research Programme (NCHRP) 500: Volume 6: A Guide for Addressing Run-Off-Road Collisions, 2003 was a seminal work in Guidance for Implementation of the AASHTO Strategic Highway Safety Plan.

### 2.6.4 Roadside Geometry: Road Edge Kerbside and Shoulders

#### 2.6.4.1 Introduction

The portion of road reserve constituting the roadside can be divided into the roadside nearest to the kerb, referred to as the **nearside,** and the driver's side as the **offside**. In relation to roadsides, it is also referred to as the shoulder or outside and the median on the inside in the case of divided roadways.

The outside of a road must be designed for functionality and safety. This implies that the smooth edge of the roadside may be adapted for elements such as public transport (bus and taxi) stops or lay-bys, lane additions and lane drops associated with auxiliary lanes (passing, climbing or other speed differentials), ramps and changes in the lane and or shoulder widths.

#### 2.6.4.2 Risk

The risks of changing the roadside geometry arise where a change of speed, speed differentials and increased information load is placed on the drivers. The interaction of road geometry and driver behaviour can lead to run-off-road events, as the near side of the road is the natural side to take evasive action, specifically on undivided roads where opposing traffic must be avoided.

#### 2.6.4.3 Design

The design of public transport stops requires that the stops are preferably located on the downstream side of an intersection, but these stops also occur on link sections of rural roads. If the bus stop is provided with adequate entrance and exit tapers, it is easy for buses to move well clear of the travelled way. If space permits, a painted island can be provided between the bus stop and the travelled way so that the stop is, in effect, a short length of the auxiliary lane. The illustrations of the typical bus stop on two-lane roads come from the SANRAL Geometric Design Guide (GDG). The short exit tapers are sufficient for urban conditions, but an acceleration/deceleration length should be provided for a public transport vehicle to attain a safe speed to merge with traffic in rural areas. Wide shoulders can provide the function of acceleration lanes; however, these should formally be indicated as such.

### 2.6.5 Roadside Geometry: Medians

#### 2.6.5.1 Introduction

The roadside geometry on the driver's side/offside next to a median should not be affected by lane additions and drops, as the fast lane should be kept continuous.

In the case of a narrow median with concrete barriers, the curves increase or decrease (curve left/curve right) sight distance and drainage channels to catch the stormwater running to the inside due to super-elevation.

Median cross-over crashes are particularly severe on high-speed roads, as the divided roads (such as freeways) are high-volume roads where a vehicle driving into the opposing traffic stream can hit multiple vehicles and cause secondary crashes. With low law-enforcement levels, drivers also attempt to make U-turns on the divided road, although prohibited.

Median side drainage channels are provided where a concrete median barrier is provided. Vehicles must be able to traverse these drains without breaking and trapping their wheels.

The provision of median barriers on urban expressways (dual carriageway roads with at-grade intersections) and median bus stops for Bus Rapid Transit systems may be required to guide pedestrians to controlled crossings at traffic signals. These barriers will be sufficient to protect pedestrians unless there is a risk of vehicles encroaching onto the median or into the bus stops.

#### 2.6.5.2 Risk

The risks of run-off-road events leading to cross-over crashes are low. They occur when the median area is used for evasive action if the traffic comes to a stillstand, forms backward shock waves and the driver brakes too late. Median side encroachments can also result in a left-hand curve when the driver turns too late.

Median cross-over crashes at high speed are rare but of catastrophic consequences.

The risk of vehicles driving over a median side drain and punching through is low, as is the risk of a second vehicle driving into an existing broken drain.

The risk of pedestrian-vehicle conflict on median islands or bus stops at busy intersections on expressways/dual carriageway roads can be high.

#### 2.6.5.3 Design

Forward sight distance must be provided by widening the inside shoulder or using anticipatory sight distance as the norm. The inner shoulder has been widened, which becomes a potential area for run-off-road events.

The design of stormwater channels on the median side must provide covers that can withstand the loads imposed by heavy vehicles and are made of material that is non-ferrous to pre-empt theft.

Where warranted, barriers should be provided to prevent cross-over crashes and U-turns.

A programme to retrofit medians with cross-over barriers will be based on risk assessments and priorities to implement the highest benefit to cost ratios.

The provision of anti-glare screens must be considered in conjunction with median barriers. If screens are justified, they should be mounted on a concrete barrier.

The provision of median barriers on expressways/dual carriageway roads for vehicles and pedestrians must be determined from traffic, cycle and pedestrian volume and conflict studies.

Typical vehicle median barriers are back-to-back W-beam or cable barriers for wide unsurfaced medians and concrete barriers where carriageways are close together.

### 2.6.6 Recovery Area

#### 2.6.6.1 Introduction

Design for Safety is intended to guide road designers regarding basic principles and key performance indicators, whereby road designs can be evaluated in terms of current safety best practices. The various elements of design are usually treated systematically. Guidelines regarding standards development for each roadway element are discussed in Volume 2.

The clear roadside zone refers to the design principle of providing an unobstructed, traversable area beyond the edge of the travelled way to recover an errant vehicle. The clear zone is located adjacent to and measured from the edge of the travelled way. The clear zone includes road shoulders, motorcycle lanes and auxiliary lanes but excludes those auxiliary lanes that act as through lanes.

Roadway design strategies for providing clear zones are as follows, in order of preference:

- Remove the obstacle;
- Redesign the obstacle for safe traversal;
- Relocate the obstacle further from the roadway (or move the roadway further from the obstacle);
- Reduce obstacle severity (make it breakaway);
- Shield the obstacle; and
- Delineate the obstacle when it is determined to leave the obstacle.

#### 2.6.6.2 Risk

The accelerating growth of road transportation causes increasingly complex problems of wide interest to road authorities in South Africa – particularly road safety problems – and calls for an urgent address to ensure commensurate mitigation measures caused by high traffic density on South African roads.

The design of safe roadways is based upon certain basic assumptions regarding the vehicle's characteristics, the driver and the road. Road traffic crashes, to varying degrees, are caused by defects in the vehicle, the driver and the road, or combinations of these defects. Design for Safety will focus on designing roads that provide a user-friendly environment, permitting vehicles and their drivers to travel safely. Due consideration should be given to the limitations of human driver factors (for example, reaction time and perception ability) and the physical and driving characteristics of the vehicle (for example, braking capability). Together with the physical constraints of the road itself (for example, skid resistance), these considerations provide a framework for safe road design.

#### 2.6.6.3 Design

Roadside design criteria generally include a recommendation for an unobstructed roadside area with relatively flat slopes. However, satisfying this principle often results in higher construction costs due to extra cross-section widths, increased crossroad structure lengths, and additional right-of-way. An objective analysis of the actual effectiveness of clear recovery areas in reducing the frequency and severity of run-off-road crashes are necessary to assure cost-effective designs. The analysis should consider cost and safety related to road type, average daily traffic, vehicle speed and road geometry.

The need for RRS implies the inability to provide a safe roadside or median based on constraints and failures in crashes. The greatest need in South Africa will be for the retrofitting of RRS on existing roads that are hazardous. RRS is often installed following a crash that highlights the hazard, but it may not be the most hazardous situation on the road network. The needs must first be determined on a network level through road safety assessments, followed by road safety appraisals for identified priorities. The designs should be subjected to road safety audits.

Specific hazardous situations arise from the lack of pedestrian walkways in rural and urban areas, causing pedestrians to walk on the surfaced roadway to avoid muddy verges. The best location for walkways is against the road reserve.

### 2.6.7 Kerbs

#### 2.6.7.1 Introduction

Road kerbs are an important element of a road section that help lessen the effects of run-off-road incidents. They serve several purposes:

- Retaining the carriageway edge to prevent 'spreading' and loss of structural integrity;
- Acting as a barrier or demarcation between road traffic, pedestrians, and other hazards;
- Providing a physical 'check' to prevent vehicles from leaving the carriageway; and
- Forming a channel along which surface water can be drained.

#### 2.6.7.2 Risk

The risk of kerbs destabilises vehicles, especially two-wheeled vehicles, when the kerb is hit at a shallow angle by redirecting the wheels or hitting the kerb at a deep angle and damaging the wheels or through vertical acceleration. The SANRAL GDG specifies that no kerbs may be used at design speeds > 80 km/h.

In low-speed urban environments, kerbs can effectively protect hazards, and a horizontal clearance of 0.5 m should be provided behind the kerb.

#### 2.6.7.3 Design

Besides retaining the carriageway edge to prevent erosion and loss of structural integrity, kerbs are significant in providing physical 'check' to prevent vehicles from leaving the carriageway in urban areas. Kerbs can be marked with a reflecting paint to assist the driver with adequate visibility and driveway delineation.

The choice of barrier versus mountable kerbs in urban areas must be considered from the function of the kerb, such as controlling parking and the safety implication for encroaching vehicles.

High barrier kerbs are often used to define the inner circle or a roundabout. These kerbs are hazardous for the driver that overshoots the roundabout.

The design of intersections where pedestrian crossings (conforming to universal access requirements) must compete with space for a traffic signal, sign and lamp poles, often requires that kerbs define the paths. Poorly designed intersections where kerb cuts (pedestrian ramps) for universal access have been retrofitted have led to the removal of kerbs and, therefore, the protection they provide to pedestrians.

### 2.6.8 Fixed Objects and Landscaping

#### 2.6.8.1 Introduction

Fixed objects such as bridge piers and abutments, bases for light poles and direction signs (gantry or cantilever-mounted) are road elements that are unavoidably positioned within the clear zone. Trees and hard landscaping (stone pitching) are optional elements that must be considered functional and not cause an undue hazard. Trees should be removed from the clear zone and replaced with low shrubs. No hard landscaping such as natural rocks and boulders, flowerpots and statues should be allowed on rural and high order or urban major arterial roads.

#### 2.6.8.2 Risk

All fixed objects in the functional area of the road, typically over the full road reserve width, become potential rigid hazards that can lead to serious and catastrophic events. The higher the operational speed, the more severe the consequences of hitting a fixed object

#### 2.6.8.3 Design

All necessary fixed objects must be evaluated against the typical Roadside Design Manuals prescribing the process for dealing with identified roadside hazards in order of priority:

- Remove the hazard;
- Redesign the hazard so that it can be safely traversed or contacted;
- Relocate the hazard to reduce the probability of it being traversed or contacted;
- Reduce the severity of the hazard;
- Shield the hazard; and
- Delineate and increase the driver's awareness of the hazard when other mitigation measures cannot be made to work. However, the designer should first approve and document why mitigation measures cannot work.

The design of a shield is typically a road restraint system such as a barrier. The design must be done following the section on barriers. The shield can also be a crash cushion.

### 2.6.9 Road Signs, Traffic Signals, Advertising Sign Support, and Breakaway Supports

#### 2.6.9.1 Introduction

Regulatory, warning, guidance and direction signs are essential roadside furniture. The Southern African Development Community SARTSM Volume 1 Chapter 1 Section 1.6.1.6 states:

'It should be recognised that sign supports may represent significant hazards to road users. Therefore, they must be sited to minimise this risk and be provided with protective devices if necessary. Various road authorities have standards in this regard that should be complied with'.

Road signs must also be located for optimal functioning. As a general rule, a road sign should be visible from a distance in metres numerically equal to the operating speed of the road in kilometres per hour.

Section 1.6.1.2 of the SARTSM states:

The position of a sign can be specified in three ways, namely:

- Longitudinally in relation to the roadway alignment;
- Laterally in relation to the roadway cross-section; and
- Vertically.

In most guidelines regarding longitudinal sign placing, relatively wide tolerances are assumed, whereas tolerances in lateral and vertical positioning are much lower and given for permanent road signs in Table 1.3 of the SARTSM.

Advertising signs must be controlled rigorously by following the road authority policies, advertising and signage by-laws and the South African Manual for Outdoor Advertising Control. Supports often are, by necessity, rigid pillars or posts that need to be located far from the roadway and remain subject to the process given under Section 2.6.8 (Fixed Objects and Landscaping).

Breakaway support safely displaced under vehicle impact, whether the release mechanism is a slip plane, plastic hinges, fracture elements or a combination of these. Rigid support forms a fixed object that can be hit when running off the road.

If roadside furniture, such as lamps, signs and signal posts, is positioned in the general pedestrian walkway, pedestrians tend to often walk in the street.

#### 2.6.9.2 Risk

Any signpost, from the humble wooden post to the steel sign gantry, is a potential hazardous object in the path of a run-off-road vehicle. The risk must be assessed in terms of the operating speed, offset from the road edge,

#### 2.6.9.3 Design

Often overlooked because the wooden poles used in South Africa may seem to be less hazardous, they can cause severe impact damage on light vehicles, be fatal for motorcyclists and cyclists. The practice in South Africa to drill two large diameters (50 mm) holes near the bases of the poles to facilitate breaking should be continued. High mast lighting, large gantry signs and billboard signs have strong steel columns, and these should be protected utilising barriers or crash cushions.

Traffic signal poles are very vulnerable on medians. Consideration must be given to provide overhead cantilever fixtures.

Designed steel breakaway poles typically for larger signs have not found favour in South Africa. This may be due to low crash rates or the absence of claims against the road authorities. They should be considered in the high-risk area as an alternative to shielding.

### 2.6.10 Lighting

#### 2.6.10.1 Introduction

Lamp posts are often near the road edges in urban areas to maximise the illuminated street area. Steel posts are most common and typically consists of a bolted footing, leaving the anchored base to be used again. However, such a design is not of the breakaway type in the sense of reducing the severity of an impact. Fibreglass posts have been used in coastal areas due to corrosion problems with steel, and these posts do break at lower impacts. Wrongdoers have been known to shake these posts until the luminaires fall off or the post snaps from brittle failure.

#### 2.6.10.2 Risk

Lamp posts are close to the road and are typically strong, constituting significant hazards in run-off-road events on freeways, approaches to town and cities (rural urban transition), arterial roads (dual carriageway typically on the single median carriageway on verges).

#### 2.6.10.3 Design

Care must be taken to locate such posts safely and not in line with possible run-off-road risks. On high-speed roads with median lights, continuous barriers with sufficient working width between barriers and lamp posts can be considered to protect the lamp post and prevent median crossovers.

### 2.6.11 Drainage Systems (Drains, Inlets and Safety Treatment)

#### 2.6.11.1 Introduction

Stormwater management is essential to protect drivers from excessive road surface run-off and collect and dispose of run-off into natural watercourses. Road drainage can be broadly divided into longitudinal and transverse structures.

Longitudinal structures are typically lined, or unlined side drains in cuttings and open channels for conveying water over a longer distance. They are usually parallel to the roadway itself.

Transverse structures include road-over-river bridges and precast concrete, metal or cast-in-situ culverts. High-level bridges are provided with balustrades or parapets as a matter of policy, although certain balustrade railings provided in the past have no certifiable containment level. Low-level bridges and low-volume local roads are designed to overflow, and the driver must be alert to signs of local flooding. Culvert headwalls are often problematic because they constitute several hazards due to their sheer number. Some headwalls are located quite far beneath the shoulder, while others rise to the level of the shoulder.

#### 2.6.11.2 Risk

Side drains (lined or unlined and properly maintained) can act as part of the recovery area next to the shoulder. Unless the side drain is eroded and lower than the roadway, they do not pose a risk.

Channels parallel to the road are a significant risk for run-off-road vehicles that will be trapped in the channel.

Example of a channel parallel to the road with significant risk

Bridges with substandard rails (balustrades or parapets) pose a high risk as a bridge is typically narrow and can accommodate pedestrians as well. Run-off-road events can occur due to traffic interaction, and the vehicle can drive off the bridge.

Culvert headwalls are fixed hazards to vehicles leaving the road and going over the shoulder breakpoint of the road.

### 2.6.11.3 Design

Lined side drains must be designed to carry heavy vehicle wheel loads.

Channels parallel to the road must be protected with barriers designed per this manual.

A new road-over-river bridge is designed with F-shaped parapets, and the containment levels are better than those of H4b.

Old bridges with substandard barriers must be refitted over time based on priority determined by road class, function, traffic volume and speed.

Typical lined V-drain

Culvert headwalls that protrude up to the level of the road must be protected with barriers designed as per this manual. Care must be taken that the anchor lengths (terminals) and functional lengths (length of need) are provided; otherwise, the barriers become expensive delineators.

The provision of concrete side drains in road cuttings, followed by the cut face at varying slopes depending on the stability of the material, results in narrower clear zones than in low fill situations. The designs of the concrete side drains vary from shallow and safe to deep trapezoidal and unsafe. The side drain can be viewed as a foundation for an RRS system, and a concrete barrier can be used as a retaining wall.

## 2.6.12 Bodies of Water

### 2.6.12.1 Introduction

Bodies of standing water present a specific hazard because vehicles submerged when landing in water can trap occupants and lead to drowning. Providing RRS next to bodies of water is generally dictated via a policy similar to the provision of minimum balustrade standards on bridges.

### 2.6.12.2 Risk

The risk of running off-road is related to the road geometry and other features, but the consequential risk is higher if the vehicle ends up in water deeper than 1 m.

### 2.6.12.3 Design

The length of protection plus anchor lengths must be determined next to bodies of standing water and installed as per this manual.  The length of the barrier was not adequately determined in the photo, while the bull nose terminal is also not accepted.

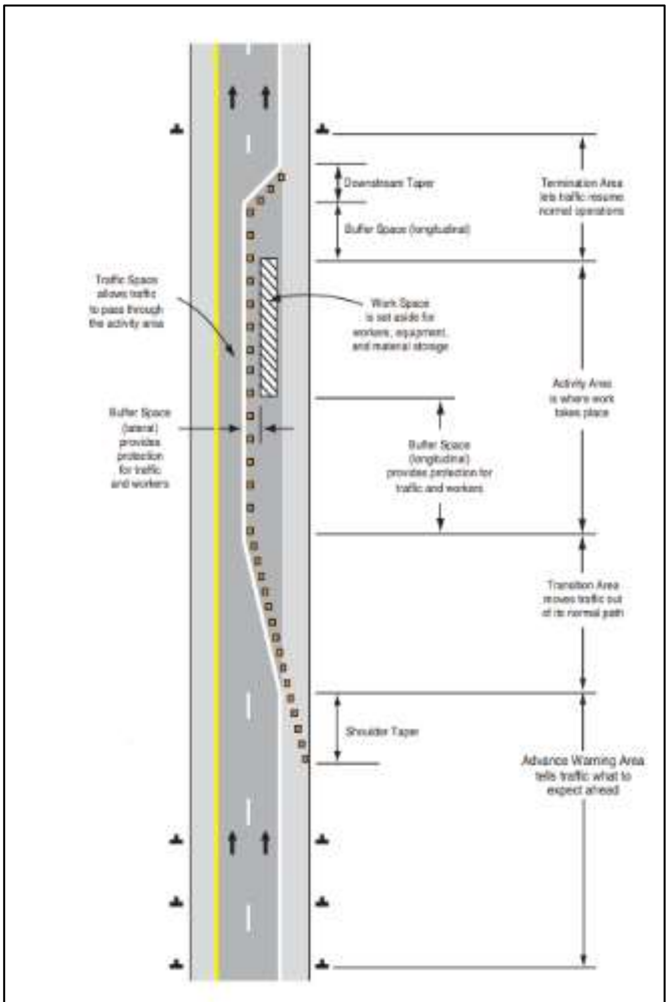
Barier too short, bull nose unacceptable

## 2.6.13 Temporary Barriers (Work Zones)

### 2.6.13.1 Introduction

The Road Traffic Signs Manual Volume 2 Chapter 13 states:

"The temporary and continually variable nature of road construction and maintenance operations on roadways that are open to traffic makes such sites potentially more dangerous than a permanent hazard. Even a driver familiar with the route cannot rely on his previous knowledge to predict conditions. Exclusive signs with a yellow background are used to identify temporary conditions from permanent ones".




Work Zone protection

The Austroads 2019 Guide to Temporary Traffic Management Part 2: Traffic Management Planning states that safety is the highest priority. The compilation of a Traffic Management Plan is the start of the process.

Traffic Management Plans control the risks for workers and the general public associated with work on or adjacent to the road. These plans need to be devised while remaining mindful that any feature placed within the road environment can risk road users. This is particularly so for vulnerable road users such as cyclists, pedestrians and the mobility impaired. Legibility of the site is essential, and road users must quickly understand the traffic management measures in use. Attention to detail when locating signs, barriers and other traffic control devices is essential.

#### 2.6.13.2 Risk

Drivers and riders can be distracted by the construction activities and get confused, leading to run-off-road events. There is also the risk of construction vehicles crossing or merging from the work zones. Construction workers are at great risk when working next to the trafficked lanes.

#### 2.6.13.3 Design

In general, speed limits in work zones are lower than the adjacent roads to protect the workers. The Road Traffic Signs Manual Volume 2 Chapter 13 Section 13.1.3 Norms to be Applied to Roadworks Signing states:

"Speed limits should be applied realistically and should, where appropriate, be altered to suit changing local conditions and/or time of day".

The first task is to keep vehicles on the intended paths, and this implies that the warning, regulatory, and guidance signs must be in place with proper delineation. Work zones where workers are present should be delimited with designed barriers.

Section 13.5.4 of the Road Traffic Signs Manual states:

"Barriers must be sufficiently fixed to give physical protection to traffic and workers alike. Typical barriers are moveable/portable steel or concrete section systems mounted following prevailing SANS requirements".

The design of temporary RRS can therefore be different from what is designed for permanent situations. Despite the lower speeds, the designer must consider construction equipment. The range of risks to be considered in designing for traffic accommodation vary from site to site, stage of construction and daily activities. The designer must consider and balance measures that meet the road users' needs while accommodating construction requirements (Austroads 2019).

Propriety products must be tested to EN 1317 requirements at the place of manufacture and used following the specifications.

It is common for South African contractors to use W-shaped steel guardrails, which are commonly available; however, they are not correctly fixed to posts with the required anchorage. Often the barriers are bolted to drums or trestles. These barriers cannot act as designed and become mere delineators.

## 2.6.14 Vehicle Arrestor Beds

### 2.6.14.1 Introduction

Arrestor beds are designed to reduce the risk associated with out-of-control heavy vehicles on long steep grades. They are preceded by runaway-vehicle escape ramps and often entail a compulsory stop for brake checking before acceleration downhill.

The following factors lead to the need for implementing or using arrestor beds:

- Gradient (long, continuous and steep);
- Repeated driver error such as failure to downshift gears;
- High incidence of equipment failure such as defective brakes;
- Driver inexperience with the vehicle;
- Unfamiliarity with the preventing gradients at a specific location;
- Driver impairment due to fatigue or alcohol; and
- Inadequate warning signing of a significant downgrade.

Marian Hill arrestor bed

Arrestor beds are designed to bring a heavy vehicle to a safe stop without severe injury or damage to adjacent property or other road users. A full-width level arrestor bed obtains deceleration rates of between 5 m/s$^2$ and 6 m/s$^2$ without using the vehicle's brakes (a 10% down gradient on the bed surface can reduce the deceleration by approximately 1 m/s$^2$). Higher deceleration rates must be avoided as inadequately restrained vehicle occupants, or insecurely attached cargo may shift forward, causing damage.

The arrestor beds used in South Africa are descending grade ramps and are typically constructed parallel and adjacent to the through lanes of the road. They require loose 'pea gravel' aggregated to optimise rolling resistance and slow the vehicle. The length of the arrestor bed depends on the preceding gradient and the deceleration characteristics of the aggregate, which should be rounded, not flaky. The material must be properly maintained by regular fluffing (ploughing and ripping) and replaced if too much sand and dust have contaminated the matrix. Stormwater drainage from the bed needs to be carefully considered at the detail design stage.

#### 2.6.14.2 Risk

The risk of runaway trucks are high, even if the number of failures is of a smaller amount, but the consequences can be catastrophic. The high cost of arrestor beds and maintenance has reduced this application to fewer than 15 sites in South Africa.

#### 2.6.14.3 Design

Engineering judgement is required to determine the location of arrestor beds. Relevant factors to be considered include:

- The location of crashes;
- The length of downgrade;
- The conditions at the bottom of the grade;
- The percentage of heavy vehicles;
- Horizontal alignment; and
- Topography (i.e., effect on the cost of earthworks).

The final judgement must be founded on a positive benefit to cost ratio.

The Mooi River and Marion Hill Toll Plazas, and the Oshoek border gate are examples of the toll booths and border control buildings at the bottom of steep grades. The crash history brought the realisation that new toll plazas and other control sites should only be located at the top of a hill.

### 2.6.15 Boom Gates (Railway Level Crossings)

#### 2.6.15.1 Introduction

Typical Railway Level Crossing

Railway level crossings represent safety-sensitive environments that require high-level road safety measures to ensure fatalities are prevented. Waiting motorists often lose patience where roads intersect with railway lines and undertake risky manoeuvres even when the signal warns vehicles about an approaching train. Safety at railway level crossings should be upgraded strictly regarding signals, boom gates and sight distance. The installation of boom gates is recommended because traffic lights have been proved insufficient to prevent all motorists from crossing when warned not to.

#### 2.6.15.2 Risk

The risk of an incident is related to the same factors for warrants for booms as listed above. Figure 10 shows the number of collisions between rolling stock and road vehicles. While the risk of an incident is relatively low, the Rail Safety Regulator has the objective to reduce incidents and severity.

#### 2.6.15.3 Design

The Road Safety Regulator reviewed the design of railway level crossings and led to the SANS 3000 -2-2-1 Technical requirement for engineering and operational standards: Track, civil and electrical infrastructure – Level Crossings, 2012.

When warranted, booms are the most cost-effective measure to prevent encroachment onto the railway lines. The design of booms is dictated by the products available.

The use of barriers obstructing vehicles such as tilt-up so-called hostile vehicle barriers or bollards is not recommended.

### 2.6.16 Pedestrian and Cyclist (NMT) Parapets and Rails

Apart from Class 5 roads, aim never to have pedestrians walking on the roadway.

On arterials, separate walkways should be provided, and on collector or access roads, kerbs should be used to separate vehicles and pedestrians and to protect pedestrians.

Where universal access requires a smooth transition from the walkway to the road, bollards may be used to protect / separate vehicles and pedestrians.

Examples of bollards protecting pedestraints in urban areas

In low-speed urban areas, bollards provide effective protection for pedestrians against traffic.

#### 2.6.16.1 Protection of Pedestrians at Intersections

Recently proposed Highway Code amendments in the United Kingdom should be standardised and applied similarly in South Africa to ensure higher levels of safety of cyclists, pedestrians and animal-powered transport (NMT). Cyclists should be given more favourable priority at junctions. Pedestrians would benefit from more clear priority when crossing or waiting to cross public roads.

Protected pedestrian walkway

The primary stipulations required in a legislated code of conduct to ensure safety at intersections are as follows:

- Introduction of a published hierarchy of road users which ensures that road users who can do the greatest harm have the greatest responsibility to reduce the danger or threat they may pose to others;
- Clarification of existing rules on pedestrian priority inside road reserves to compel motorists to give way to pedestrians crossing or waiting to cross a carriageway in a developed environment (or where pedestrians form the majority of road users); and
- Provision of guidance on cyclist priority at junctions to advise drivers to prioritise cyclists at junctions when travelling straight ahead.

#### 2.6.16.2 Pedestrian Restraint

Clear vision pedestrian guardrails are used to give pedestrians as wide a field of vision as possible to prevent them from unwittingly walking into the road at potentially hazardous locations. Pedestrian crossings, schools, metro and train access areas, and shopping areas should be furnished with modular design systems, e.g. standard panel lengths, widths or height.

Their safety is derived from maximising visibility between pedestrians and vehicles. The Clear Vision Design allows even small children to view oncoming vehicles and gives drivers a clearer sight of kerbside pedestrians.

#### 2.6.16.3 Separation of Walkways

The provision of walkways separated from the travel road lanes on roads helps minimise walking along with roadway crashes. Walkways can be created by either providing stabilised or paved surfaces separated from the roadway or widening paved shoulders. These treatments do not only improve the safety of pedestrians but also make pedestrian trips more attractive.

#### 2.6.16.4 Public Transport Facilities

Public transport facilities seek to address mobility in general, and their improvement constitutes pedestrians' security, comfort and dignity. Therefore, taxi, bus and train shelters, ablutions, trading spaces, signage, communication, etc., need to be designed with the commuter in mind and achieve a modal shift in commuter traffic.

### 2.6.17 Anti-Glare Screens

#### 2.6.17.1 Introduction

Anti-glare screens are generally used on high-speed dual carriageway roads. The screen is a simple arrangement of metal posts approximately 450 mm high at about a 2 m spacing with mesh in between. Damaging and theft of the anti-glare screens seems a huge problem.

Example of an anti-glare screen on a freeway

#### 2.6.17.2 Risk

Low risk of drivers getting blinded by the lights of the opposing traffic stream can lead to a run-off-road towards the median or median barrier or into the lane on the same carriageway.

#### 2.6.17.3 Design

The design used in South Africa was on top of concrete median barriers and had no structural significance or need to be tested as the concrete barriers will redirect the vehicles without them being elevated up to the level of the anti-glare screens.

The design of anti-glare screens has not been codified and may be similar to that of pedestrian rails, to resist collapsing if pedestrians climb over the screens mounted on top of a concrete barrier. The effective height of the rail must be used to determine overturning moments.

Headlight glare from opposing traffic is most common between opposing mainline traffic. Glare screens can be used to mitigate this condition. Other conditions for which glare screen might be appropriate are:

- Between a highway and an adjacent frontage road or parallel highway, especially where opposing headlights might seem to be on the wrong side of the driver;
- At an interchange where an on-ramp merges with a collector-distributor and the ramp traffic might be unable to distinguish between collector and mainline traffic; and

- Where headlight glare is a distraction to adjacent property owners, playgrounds, ball fields, and parks with frequent night-time activities might benefit from screening if headlight glare interferes with these activities.

Glare screening is usually not justifiable where the median width exceeds 6 m, and the ADT is less than 20000 vehicles per day.

# 3 EQUIPMENT SPECIFICATION

## 3.1 SCOPE

### 3.1.1 South African Standards


SANS 51317-2:2009
EN 1317-2:1998

SOUTH AFRICAN NATIONAL STANDARD

Road restraint systems

Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers

South African National Standards (SANS) play an essential role in setting minimum standards in South Africa, including all infrastructure elements making up the road network at municipal, provincial and national levels. The South African Bureau of Standards (SABS) also ensures that relevant international standards are considered when establishing South African standards. Many SABS standards form part of the specifications used to ensure the quality and performance of road infrastructure and ancillary road works.

In the transportation sector, the COTO has adopted several documents regarding the provision of road infrastructure, including documents in the Technical Methods for Highways and Technical Recommendations for Highways series and the COTO Standard Specifications for Road and Bridge Works for South African Road Authorities. RRS is covered in Section 11.4: *Road Restraint Systems* of the COTO Specifications.

COTO refers to many SABS specifications that need to be complied with regarding road infrastructure construction. The SABS also published specifications for road networks as part of the SANS 10400 series. These specifications deal with the manufacture and installation of road-related infrastructures, such as:

- SANS 1350: Barriers;
- SANS 121: Galvanising;
- SANS 457: Timber Posts; and
- SANS 1519: Retro-reflective Material.

An important aspect of the COTO Specifications is that provision is made for the RRS design by the contractor responsible for the road works, referred to as 'Performance-Based Systems' (Section 11.4.4), including performance requirements, performance assessment, guarantees and compliance certificates.

### 3.1.2 International Standards

Over and above South African standards, two international RRS standards may be considered in the design and specification of RRS in South Africa:

*i. European Standard*

The European Norm (EN) 1317: *Road Restraint Systems* is laid out as follows:


- Part 1: Terminology and general criteria for test methods;
- Part 2: Performance classes, impact test acceptance criteria and test methods for safety barriers;
- Part 3: Performance classes, impact test acceptance criteria and test methods for crash cushions;
- Part 4: Performance classes, impact test acceptance criteria and test methods for terminals and transitions of safety barriers;
- Part 5: Product requirements and evaluation of conformity for vehicle restraint systems;
- Part 6: Pedestrian restraint systems; pedestrian parapets (the EN has withdrawn this part);
- Part 7: Performances classes, impact test acceptance criteria and test methods for terminals of safety barriers (the EN has withdrawn this part); and
- Part 8: Motorcycle RRS reduces the impact severity of moto cyclist collisions with safety barriers (the EN has withdrawn this part).

*ii. United States of America (AASHTO)*

The National Co-operative Highway Research Programme (NCHRP): *350 Recommended Procedures for the Safety Performance Evaluation of Highway Features, 1993* was developed in the United States of America (USA) to determine the appropriate RRS for an identified hazard, based on performance criteria and risk analysis.

AASHTO published the Manual of Assessing Safety Hardware (MASH), 2009, which includes new highway safety hardware not included in previous documents. The AASHTO MASH 2009 supersedes the NCHRP: 350.

The size and weight of test vehicles in MASH 2009 were increased to reflect the increase in the size and weight of the USA passenger vehicle and truck fleet.

Although kerbing often forms an integral part of RRS, concrete kerbing and asphalt berms form part of COTO Specifications Chapter 3: *Drainage*. RRS infrastructure may also include infrastructure elements included in Chapter 3 of the COTO Specifications.

### 3.1.3 Road Restraint System Specifications in South Africa

RRS specifications in South Africa is the responsibility of SABS/TC 081/5C 10: *Construction Materials, Products and Test Methods – Road Furniture and Auxiliary Products*, which deals with 'standardisation in the field of Manufacture and Supply of Permanent and Temporary RRS, Crash Cushions, Terminals, Transitions and Pedestrian Restraint Systems, covering Terminology, General Criteria for Test Methods and Performance Classes'.

The RRS test methods fall outside the scope of the SARRSM, but this section has been included in the manual to provide manual users with the necessary background, particularly regarding performance-based RRS.

The SABS Committee agreed to adopt EN 1317 Parts 1 to 8 as SANS standards. In the United Kingdom, EN 1317 has also been adopted as a British standard. (note that EN 1317 Parts 6 to 8 have been withdrawn).

## 3.2 ROAD RESTRAINT TYPES

The EN 1317 Part 1 identifies the following RRS:

| TABLE 2: ROAD RESTRAINT SYSTEMS | |
|---|---|
| VEHICLE RESTRAINT SYSTEMS | PEDESTRIAN RESTRAINT SYSTEMS |
| Safety barriers<br>Terminals and transitions<br>Vehicle parapets<br>Crash cushions<br>Arrestor beds | Pedestrian parapets<br>Pedestrian guardrails |

The SARRSM also includes the following:

- Vehicle height or vehicle dimension restraint system;
- Rail level crossings;
- Kerbs; and
- Drainage structures.

## 3.3 VEHICLE SPECIFICATIONS

The EN 1317 refers to the following test vehicles*:

| TABLE 3: TEST VEHICLES | |
|---|---|
| VEHICLE TYPE | VEHICLE MASS |
| Car | 825 ± 40 kg |
| Car | 1300 ± 65 kg |
| Car | 1500 ± 75 kg |
| Rigid heavy goods vehicle (HGV) | 10000 ± 300 kg |
| Bus | 13000 ± 400 kg |
| Rigid HGV | 16000 ± 500 kg |
| Rigid | 30000 ± 900 kg |
| Articulated HGV | 38000 ± 1100 kg |

** Several dimensions and centre of gravity criteria are provided for each vehicle type*

It should be noted that the specific vehicles specified for RRS testing are not typical or maximum vehicles encountered on the road network but are vehicles that can be selected for the testing of a particular RRS.

Light passenger vehicles and light delivery vehicles (LDVs) are often larger and considerably heavier than the 'car' vehicle type used in the testing of RRS. The maximum vehicle mass permitted on South African roads is also well above the vehicle mass of the largest HGV applied in the RRS testing.

Note that AASHTO MASH 2009 includes larger and heavier test vehicles in the car and pick-up truck (LDV) vehicle classes.

## 3.4 CRITERIA FOR MEASUREMENT DURING TESTS

### 3.4.1 Acceleration Safety Index

The Acceleration Safety Index (ASI) is intended to measure the severity of the vehicle motions for a person seated in the vehicle and is calculated from measurements taken during a test, as prescribed in EN 1317 Part 1.

### 3.4.2 Theoretical Head Impact Velocity

The Theoretical Head Impact Velocity (THIV) concept has been developed to measure the occupant impact severity for vehicles involved in a collision with road vehicle restraint systems and is calculated from measurements taken during a test as prescribed in EN 1317 Part 1.

### 3.4.3 Post-Impact Head Deceleration

It is assumed that post-impact, the occupant's head remains in contact with the surface of the test vehicle's interior for the remaining contact period and experiences the same deceleration as the test vehicle, hence the name Post-Impact Head Deceleration (PHD).

During the testing of RRS, the dynamic deflection of the restraint system and the test vehicle's path are measured.

EN 1317 also provides a procedure for calculating the following criteria regarding the impact on occupants of test vehicles.

## 3.5 IMPACT SEVERITY LEVELS (CLASSES)

### 3.5.1 Safety Barriers

EN 1317 Part 2 provides Impact Severity Levels based on the measurement criteria defined above (ASI, THIV and PHD).

Impact Severity Levels are determined according to the table below.

<table>
<tr><th colspan="4">TABLE 4: IMPACT SEVERITY LEVELS OF SAFETY BARRIERS</th></tr>
<tr><td>IMPACT SEVERITY LEVEL</td><td colspan="3">INDEX VALUES</td></tr>
<tr><td>A</td><td>ASI ≤ 1.0</td><td rowspan="3">and</td><td rowspan="3">THIV ≤ 33 km/h<br>PHD ≤ 20 g*</td></tr>
<tr><td>B</td><td>1.0 < ASI ≤ 1.4</td></tr>
<tr><td>C</td><td>1.4 < ASI ≤ 1.9</td></tr>
</table>

** g = 9.81 m/s²*

### 3.5.2 Crash Cushions

Vehicle Impact Severity Levels for crash cushions are provided in EN 1317 Part 3 and are tabulated below.

| TABLE 5: VEHICLE IMPACT SEVERITY VALUES | | | |
|---|---|---|---|
| IMPACT SEVERITY LEVELS | INDEX VALUES | | |
| A | ASI ≤ 1.0 | THIV ≤ 44 km/h in Tests 1, 2 and 3<br>THIV ≤ 33 km/h in Tests 4 and 5 | PHD ≤ 20 g |
| B | ASI ≤ 1.4 | THIV ≤ 44 km/h in Tests 1, 2 and 3<br>THIV ≤ 33 km/h in Tests 4 and 5 | PHD ≤ 20 g |

### 3.5.3 Transitions

Vehicle impact severity classes for terminals are specified in EN 1317 Part 4 and are tabulated below.

| TABLE 6: TERMINALS: VEHICLE IMPACT SEVERITY CLASSES | | | |
|---|---|---|---|
| IMPACT SEVERITY CLASSES | INDEX VALUES | | |
| A | ASI ≤ 1.0 | THIV < 44 km/h in Tests 1 and 2<br>THIV < 33 km/h in Tests 4 and 5 | PHD ≤ 20 g |
| B | ASI ≤ 1.4 | THIV < 44 km/h in Tests 1 and 2<br>THIV < 33 km/h in Tests 4 and 5 | PHD ≤ 20 g |

## 3.6 IMPACT TEST CRITERIA

### 3.6.1 Safety Barriers

Eleven (11) vehicle tests are defined in EN 1317 Part 2 for testing safety barriers. Vehicle impact test criteria for safety barriers are stipulated in the table below.

TABLE 7: VEHICLE IMPACT TEST CRITERIA

| TEST | IMPACT SPEED (km/h) | IMPACT ANGLE DEGREES | TOTAL VEHICLE MASS (kg) | TYPE OF VEHICLE |
|---|---|---|---|---|
| TB 11 | 100 | 20 | 900 | Car |
| TB 21 | 80 | 8 | 1300 | Car |
| TB 22 | 80 | 15 | 1300 | Car |
| TB 31 | 80 | 20 | 1500 | Car |
| TB 32 | 110 | 20 | 1500 | Car |
| TB 41 | 70 | 8 | 10000 | Rigid HGV |
| TB 42 | 70 | 15 | 10000 | Rigid HGV |
| TB 51 | 70 | 20 | 13000 | Bus |
| TB 61 | 80 | 20 | 16000 | Rigid HGV |
| TB 71 | 65 | 20 | 30000 | Rigid HGV |
| TB 81 | 65 | 20 | 38000 | Articulated HGV |

### 3.6.2 Crash Cushions

Tests of crash cushions are defined in EN 1317 in terms of the following:

- Approach direction of vehicle and impact position;
- Test vehicle mass; and
- Impact speed.

Vehicle impact test criteria for crash cushions are tabulated below.

TABLE 8: VEHICLE IMPACT TEST CRITERIA FOR CRASH CUSHIONS

| TEST * | APPROACH | TOTAL VEHICLE MASS (kg) | VELOCITY (km/h) | FIGURE ILLUSTRATION |
|---|---|---|---|---|
| TC 1.1.50<br>TC 1.1.80<br>TC 1.1.100 | Head-on centre | 900<br>900<br>900 | 50<br>80<br>100 | 1 |
| TC 1.2.80<br>TC 1.2.100 | Head-on centre | 1300 | 80<br>100 | 1 |
| TC 1.3.110 | Head-on centre | 1500 | 110 | 1 |
| TC 2.1.80<br>TC 2.1.100 | Head-on, ¼ vehicle offset | 900 | 80<br>100 | 2 |
| TC 3.2.80<br>TC 3.2.100 | Nose (centre) at 15º | 1300<br>1300 | 80<br>100 | 3 |

| TABLE 8: VEHICLE IMPACT TEST CRITERIA FOR CRASH CUSHIONS | | | | |
|---|---|---|---|---|
| TEST * | APPROACH | TOTAL VEHICLE MASS (kg) | VELOCITY (km/h) | FIGURE ILLUSTRATION |
| TC 3.3.110 | | 1500 | 110 | |
| TC 4.2.50<br>TC 4.2.80<br>TC 4.2.100<br>TC 4.3.110 | Side impact at 15º | 1300<br>1300<br>1300<br>1500 | 50<br>80<br>100<br>110 | 4 |
| TC 5.2.80<br>TC 5.2.100<br>TC 5.3.110 | Side impact at 165º | 1300<br>1300<br>1500 | 80<br>100<br>110 | 5 |

** TC x·y·z with*
*x = Approach angle and position; y = Test vehicle mass class; and*
*z = Impact speed.*

Note that test vehicles are limited to cars.

### 3.6.3 Terminals and Transitions

Test criteria and performance classes for terminals are specified in EN 1317 Part 4 and include the following:

- Performance class: P1 to P4 according to increasing containment capacity;
- Location: Upstream (U) or downstream (D) of barrier or both (A);
- Vehicle mass (kg): 900, 1300 or 1500. Note that test vehicles are limited to cars;
- Impact speed (km/h): 80, 100 or 110; and
- Terminal test code: TC x. y. z where x = Approach, y = Test vehicle mass index and z = Impact speed.

## 3.7 PERFORMANCE CLASSES

### 3.7.1 Safety Barriers

EN 1317 Part 2 provides several levels of performance of safety barriers according to three main restraint criteria:

- The containment level (ten levels are specified) based on specified acceptance tests;
- Impact severity levels A and B, based on ASI, THIV and PHD; and
- The working width expresses the deformation of the restraint system.

When tested according to the impact criteria specified for a particular test (vehicle type, impact speed, impact angle and vehicle mass) applicable to a particular containment level, the safety barrier shall conform to the requirements in respect of the following:

- Impact severity (ASI, THIV and PHD);
- Working width (eight classes of working width (W1 to W8) and working width ranging from ≤ 0.6 m to ≤ 3.5 m);
- Impact test acceptance criteria for barriers. Safety barriers shall contain the vehicle without breakage, penetration of the passenger compartment or posing a hazard to other traffic. The dynamic deflection and working width shall be determined and quoted in the test report; and
- Impact test acceptance criteria for test vehicles. The vehicle shall remain upright, and its centre of gravity shall not cross the centreline of the deformed system and specified limits on the vehicle path after leaving the barrier after impact. The Vehicle Cockpit Deformation Index And Severity Index may not be exceeded.

### 3.7.2 Crash Cushions

Acceptance of a crash cushion is determined as a function of the following:

- Vehicle impact severity;
- Vehicle trajectory;
- Distribution of test vehicle and crash cushion debris;
- Containment level; and
- Crash cushion deflection.

Vehicle impact test criteria apply to two types of crash cushions: redirected (R) crash cushions, which retain and redirect vehicles, and non-redirected (NR) crash cushions, which retain but do not redirect vehicles.

Acceptance tests are specified separately for R, and NR crash cushions, based primarily on the vehicle speed (50, 80, 100 and 110 km/h) – a reduced performance level class 80/1 is also included.

It should be noted that tests are only specified for cars, buses, or heavy vehicles.

Crash cushion behaviour shall comply with the following:

- No element shall penetrate the passenger compartment;
- No element (mass > 2 kg) shall become detached; and
- No major element shall impede the path of adjacent traffic.

The deformed crash cushion shall not encroach into the front surface of the obstacle.

The rest of the detached element shall be considered to determine the displacement classification (D1 to D8) within a range of 0.5 m to 3.0 m.

Test vehicle behaviour shall comply with the following:

- The vehicle shall remain upright;
- The post-impact trajectory is controlled by the specified exit box of specified dimensions;
- Vehicles shall not intrude on the front face of the obstacle; and
- The redirection zone (Z1 to Z4) is determined by the distance encroached by the test vehicle, measured from the crash cushion envelope (ranges between 4 m and 6 m).

### 3.7.3 Terminals and Transitions

Terminals are the beginning and/or end of safety barriers and are required to provide a smooth transition from no containment to the containment provided by the safety barrier without introducing additional hazards for head-on impacts.

Transitions provide a connection between two different safety barriers with different stiffness.

Tests include three-speed classes (80, 100 and 110 km/h) for test vehicle mass classes 900, 1300 and 1500 kg) – note that tests apply to cars only.

Terminal behaviour shall comply with the following:

- Elements of the terminal shall not penetrate the passenger compartment of the vehicle; and
- No part of the terminal shall become detached and rest outside the permanent displacement zone (0.5 m to 3 m from the centre line of a barrier).

Test vehicle behaviour shall conform to the following:

- The vehicle shall not overturn; and
- The vehicle shall be contained within the dimensions of the exit box for terminal classes Z1 to Z4 (4 m to 6 m on the approach side and 4 m to unlimited on the departure side).

## 3.8 CONTAINMENT LEVELS AND WORKING WIDTHS

Barriers are specified in terms of two parameters, i.e. Containment Level and Working Width.

### 3.8.1 Working Width

Working Width is the dynamic deflection of a tst vehicle during the test procedure. The Working Width of a barrier at a road side feature should be specified to avoid a collision between vehicles and the feature that is being protected.

Typical working widths for semi-rigid and flexible barriers are specified in Table 9.

| TABLE 9: WORKING WIDTH | |
|---|---|
| BARRIER TYPE | WORKING WIDTH (NOT AT FIXED OBJECTS OR HAZARDS) |
| Semi-rigid | 2.1 m |
| Flexible | 3.5 m |

### 3.8.2 Containment Level


Table 10 provides a summary of the most commonly used containment levels in South Africa and Table 11 provides detail on containment level tests and the conditions where teste may be applicable.

| TABLE 10: CONTAINMENT LEVEL PRIMARILY USED IN SOUTH AFRICA | |
|---|---|
| LEVEL | CONTAINMENT LEVEL |
| N1 | Normal for car - urban |
| N2 | Normal for car - rural |
| H2 | High for buses. Selected routes where buses operate and low heavy truck volumes |
| H4b | Trucks. Routes where trucks are the design vehicle |

| TABLE 11: CONTAINMENT LEVELS | | | |
|---|---|---|---|
| CONTAINMENT LEVEL | | TEST (VEHICLE TYPE & MASS; SPEED; ANGLE) | APPLICATION |
| LOW ANGLES | T1 | TB21<br>(C1300; 80; 8) | N/A. Vehicle mass not representative |
| | T2 | TB22<br>(C1300; 80; 15) | N/A. Vehicle mass not representative |
| | T3 | TB41 + TB21<br>(SU10000; 70; 5) + (C1300; 80; 8) | Roadworks 80 km/h urban arterials |
| NORMAL | N1 | TB31<br>(C1500; 80; 20) | Roads with speeds limit ≤ 80 km/h, except locations where heavy vehicle risk has been identified |
| | N2 | TB32 + TB11<br>(C1500; 110; 20)<br>(C900; 100; 20) | Roads with speed limits > 80 km/h, except locations where heavy vehicle risk has been identified |
| HIGH | H1 | TB42 + TB11<br>(SU 10000; 70; 15)<br>(C900; 100; 20) | Roads with speed limits < 80 km/h at locations where truck risk has been identified, but articulated trucks are not expected |
| | H2 | TB51 + TB11<br>(Bus13000; 70; 20)<br>(C900; 100; 20) | Special applications at locations where heavy buses have been identified as dominant design vehicle |
| | H3 | TB61 + TB11<br>(SU16000; 80; 20)<br>(C900; 100; 20) | Locations where truck risk has been identified and where large articulated trucks are not expected |

| | | | |
|---|---|---|---|
| VERY HIGH | H4a | TB71 + TB11<br>(SU30000; 65; 20)<br>(C900; 100; 20) | Special applications at locations where 30t rigid heavy vehicle type is dominant |
| | H4b | TB81 + TB11<br>(Art38000; 65; 20)<br>(C900; 100; 20) | Locations where heavy truck rik has been identified, e.g. bridge piers |

Practitioners should note that barriers cannot contain and redirect all vehicles found on the road network and should familiarize themselves with the barrier's containment level and working width before it is specified for implementation at a specific hazardous location.

# 4 MAINTENANCE OF ROAD RESTRAINT SYSTEMS

Most systems require very little maintenance, but routine inspection is essential to identify damaged elements and ensure that RRS elements function properly. When a barrier has been damaged in a crash, the subsequent repair costs can be significant, to the point of being excessive in the case of a high crash location. It is recommended that all RRS devices are referenced and that quality control sheets be used for control purposes.

## 4.1 MAINTENANCE OF BREAKAWAY SYSTEMS

Breakaway support becomes a maintenance problem after it has been hit as it should either be repaired or replaced after impact. Therefore, the various types of breakaway supports and the components they consist of should receive consideration when selecting a particular system, as it influences maintenance cost, materials required during maintenance actions, workforce requirements and the frequency of maintenance required.

Maintenance costs include the following:

- Regular maintenance actions such as cleaning and checking specific features like bolts, post height and soil stability;
- Crash maintenance, i.e. repair of the system after impact;

- Maintenance personnel;
- Risk to maintenance personnel while performing regular and crash maintenance;
- Cost of stock of materials required to perform regular and crash maintenance;
- Vehicles required to transport maintenance personnel; and
- Other equipment used by maintenance personnel (including cell phones).

## 4.2 FLEXIBLE SYSTEMS

The dynamic deflection distance of barriers should be kept clear and free from any objects. The maintenance requirements should be determined before choosing a cable system in terms of collision and routine maintenance of the specific cable system design. The authority should be sure that:

- They can report and restore the cable systems damaged during a collision quickly enough to ensure that the cable can continuously provide adequate protection;
- The necessary materials for routine and collision maintenance are readily obtainable and affordable; and
- The maintenance personnel are adequately trained to ensure proper installation and maintenance.

## 4.3 SEMI-FLEXIBLE SYSTEMS

It is necessary to inspect W-section guardrails from time to time to ensure that nothing has happened that could jeopardise the adequate performance of the system under impact.

## 4.4 INSPECTION OF GUARDRAILS

The following aspects need to be assessed to determine possible maintenance needs:

- Does the rail show any evidence of damage, corrosion or misalignment?
- Are all splice bolts and post bolts in position and tight?
- Are all the rails attached adequately to terminals and transitions?
- Are all the rails lapped in the right direction?
- Are there any fixed objects within the deflection distance behind the guardrail?
- Are the post sizes correct?
- Are there any posts missing or badly misaligned?

- Are any of the offset blocks missing, damaged or rotated?
- Are the posts still structurally sound, firmly in position with enough support around them to develop resistance in case of an impact?
- Is there anything in front of the rail that can cause a vehicle to vault or under-ride?
- Are there any irregular curves on the rail face because of possible earlier incidents?
- Is the barrier still at the correct height?

A more in-depth inspection should be done whenever extensive repair work to the barrier is contemplated or when the road will be rehabilitated. Such an inspection would then also address the following aspects:

- The barrier rail height should be checked to ensure that it would still be at the correct height when the project is completed;
- Can the hazard be removed or modified to eliminate the need for the barrier?
- Is the entire barrier needed to shield the hazard?
- Does the barrier meet the *length of need* criteria, or should the barrier be lengthened even more?
- Are there any kerbs or slopes that would increase the risk of vaulting?
- Are the grading requirements at the terminals being met?
- Is this type of barrier still appropriate for the current traffic mix at the site?
- Is the post spacing appropriate for the available deflection distance?
- Are terminals and transitions consistent with current standards?

## 4.5 CONCRETE BARRIERS

Concrete barriers require low maintenance, and most maintenance is crash-related. However, regular inspection is essential.

## 4.6 BRIDGE BARRIERS

Bridge management systems utilise specific checklists during bridge inspections. Such bridge inspections assess the physical condition and approaches to the bridge and the extent to which the bridge can be used safely. The following are some of the factors usually addressed in such bridge assessment programmes:

- The bridge railing and supports should be structurally adequate to withstand the impact of the design vehicles;
- The post-to-deck attachments should be adequate to prevent vehicle penetration on impact;
- The vaulting potential of kerbs and sidewalks in front of the bridge railing should be assessed, and possible remedial measures considered;
- When a guardrail is used as a bridge railing, it must be installed following specifications and requirements of the road authority;
- Bridge railings must have continuity over their entire length to limit the potential of snagging;
- Particular attention should be paid to proper transitions between the approach guardrails and the bridge railing. There must be a gradual increase in lateral stiffness of the transition leading up to the main bridge railing. The connection of the transition to the main bridge railing shall have the full beam strength of the guardrail to provide continuity from one barrier to the next;
- Special attention needs to be paid to the open areas between twin bridges on freeways; and
- All standard plans should also be reviewed to correct known deficiencies and not duplicated on new construction.

## 4.7 TRANSITION SECTIONS

The transition sections should be regularly inspected as part of either a bridge inspection programme or routine inspections on the guardrails. Aspects to include in such inspections form part of the barrier and guardrail inspections discussions and will not be repeated here. A decision to replace an obsolete transition section should be seriously considered if the transition or part of the approaching guardrail was extensively damaged in a crash. If one transition at a bridge has to be replaced, it can upgrade the transitions on the other approach and end blocks. The possibility of upgrading the bridge railing to improve performance levels should also be considered.

# 5 RISK ASSESSMENT PROCEDURE

## 5.1 INTRODUCTION

Adopting a safe system approach to road safety recognises that humans as road users are fallible and will continue to make mistakes, but the built road environment should not penalise people with death or severe injury when they make mistakes. Therefore, roads (and vehicles) should both be designed to reduce the incidence and severity of crashes when they inevitably occur in a safe system.

## 5.2 CONTRIBUTION OF ROADSIDE DESIGN TO ROAD SAFETY

Many crashes on road networks, particularly in rural areas, involve run-off-road crashes. The design of the roadside features within clear zones either adversely affect road safety or contribute to a safer environment for all road users. The prime road environment safety objective is to reduce crashes and casualties by improving the road environment and traffic management.

The sides of rural roads have to accommodate various features and infrastructure such as open drains, traffic signs and their supports, and road safety barriers, while urban roads usually have to accommodate paths, public utilities, landscaping and other facilities. All roadside features and infrastructure should be designed to support the safe systems approach by minimising the roadside risk for errant drivers at greenfield sites. Therefore, road designers and practitioners can significantly contribute to crash reduction by applying best practices in the design of roadsides.

## 5.3 APPROACH

Figure 5 provides the approach for the Risk Assessment Procedure.

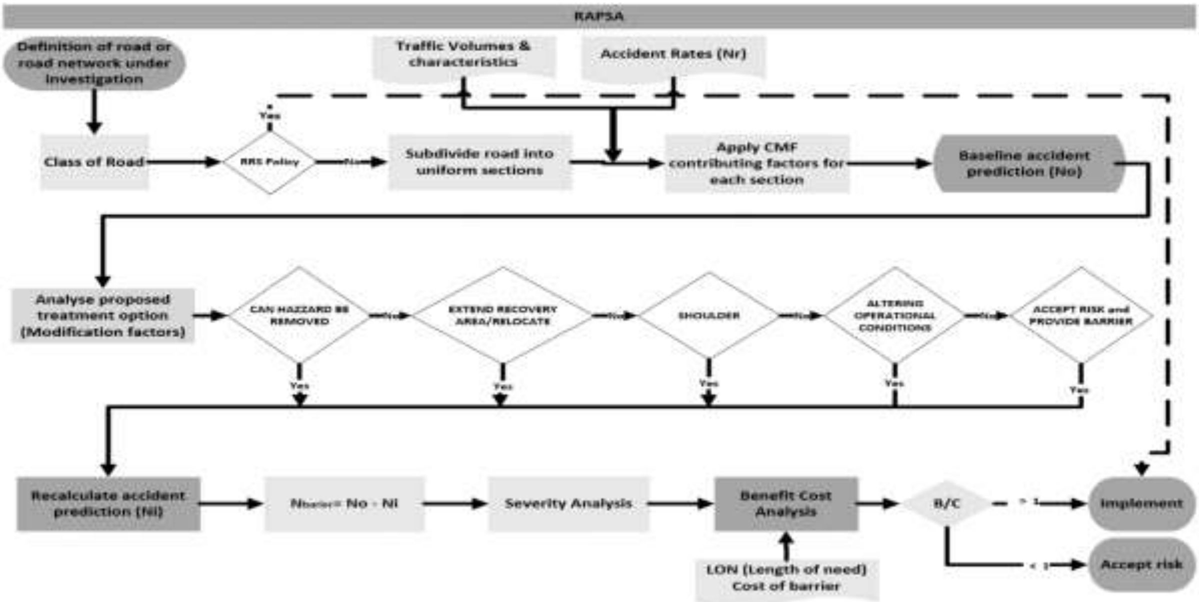



Figure 5: Risk Assessment Procedure

## 5.4 CRASH STATISTICS

Historical crash rates provide the base information for calculating predicted crash rates. Unfortunately, available accident records in South Africa are insufficient for the calibration of accident models, and a high degree of professional judgement had to be applied in the development of the procedure.

## 5.5 CRASH REDUCTION

Almost all crashes could have been prevented if the involved persons acted differently, which does not mean that the most effective way to reduce crashes is to alter people's behaviour or tendency to make errors. Effective action must aim jointly at the human element, vehicle and road. Road design can reduce the incidence of human error and the chance of a human error ending up as a crash. It can also ameliorate the severity of crashes initiated by human error.

It is not only the car driver's safety that should be considered but also that of other road users such as pedestrians, cyclists and motorcyclists, and persons occupying properties that traffic crashes might impact.

Road and roadside design for errant vehicles should involve:

- A design process that considers the safety of all road users and produces a forgiving road environment;
- Design to keep vehicles on the road;
- An assessment of the roadside and appropriate action to reduce the risks of roadside hazards through their removal or mitigation;
- Provision of road safety barriers through a risk assessment process; and
- Choice of road safety barriers through a rigorous acceptance process.

These requirements are essential to provide the safest possible environment for all road users.

## 5.6 RISK

Road design aims to achieve a reasonable and economic balance between the assessed risks of hazardous consequences and the measures needed to mitigate those risks.

Most risks, or a combination of risks, can be treated differently. The choice of treatment methods should aim to provide a cost-effective solution consistent with reducing the risk of impacting a particular hazard or hazards. Sometimes, several smaller and cheaper treatments may be just as effective as a single larger treatment, which is more expensive.

The systematic approach to risk reduction in design involves:

- Reducing the inherent hazard;
- Preventing an incident; and
- Limiting damage.

### 5.6.1 Reduce Inherent Hazard

An inherently safe design aims to either eliminate hazards or ensure that the level of roadside risk to road users is very low. While the risk associated with hazards can be reduced through engineering treatments, it should be understood that these treatments may also be hazardous to the occupants of errant vehicles.

For the following reasons, the elimination of hazards should always be preferred to adding safety devices and other layers of protection to make the hazards safer:

- Although the severity of an impact with the device or treatment may be less than an impact with the hazard that is being shielded, a hazard is still present; and
- There is always the potential for a crash due to simultaneous failure of several layers of protection or the degradation of the layers of protection in the future.

An inherently safe design is better than the use of safety devices (e.g. adding road safety barriers) that can be hazardous to road users and can also add significant maintenance costs over the operational life of the road. It should be understood that safety barriers and other safety devices are also a form of roadside hazard. They can significantly damage errant vehicles, injure the occupants, and be particularly severe with errant motorcyclists. Therefore, they are used to reduce the inherent hazard and should only be used where less severe treatments are impracticable.

While inherent safety represents the first and most desirable way to manage risk, preventing incidents and minimising damage in a crash can also be used effectively to reduce risk.

### 5.6.2 Prevent an Incident

Prevention of an incident is the second step in balanced risk reduction. In transport operations, crashes usually arise because of loss of control and/or containment (a hazardous material or vehicle). Therefore, preventing the loss of control or containment is effective risk control. Matching horizontal curve radii to the operating speed is an example of incident prevention.

### 5.6.3 Limit Damage

If a vehicle leaves the road and there is a hazard present that cannot be removed, the hazardous consequences of an incident can be limited, often through protection systems. The use of a road safety barrier to reduce impact severity is an example of limiting damage, as is the choice of a barrier that results in a less severe impact for vehicle occupants during a crash.

Protection systems can be put in place to protect against hazardous consequences if an incident occurs. Protection systems provide a backup when normal facilities for control or containment fail (i.e. when prevention of the incident fails). Road safety barriers are an example of a protection system.

## 5.7 BENEFIT/COST ANALYSIS

The primary objective of an encroachment-probability crash prediction model is to compare the various safety improvement options. The most common method of comparison is to calculate a B/C ratio.

An economic evaluation of RRS should be undertaken according to TMH 20 Socio-Economic Analysis of Road Projects and should distinguish between the comparison of mutually exclusive improvement options and the evaluation of independent RRS improvements.

A B/C analysis compares the benefits derived from a safety improvement to the direct costs associated with the improvement. Benefits are measured in terms of reductions in societal costs arising from decreases in the number and/or severity of crashes. Direct safety improvement costs include initial installation, maintenance and crash repair costs. Both costs and benefits must be discounted at the specified discount rate.

Road restraint systems' risk assessment and economic evaluation are discussed in Volume 2, Annexure A, RAPSA.

Road Traffic
Management Corporation

**Draft Guideline Document**

**South African Road Restraint Systems Manual (SARRSM)**

# VOLUME 2

# SOUTH AFRICAN ROAD RESTRAINT SYSTEMS MANUAL STANDARDS AND REQUIREMENTS

**March 2022**

ARRIVE ALIVE
A proud initiative of
The Department of Transport

DECADE OF ACTION FOR
ROAD SAFETY
2021 - 2030

**'Safe roads in South Africa'**

The Road Traffic Management Corporation is an Agency of the Department of Transport and a Member of the United Nations Road Safety Collaboration

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# Acronyms and Abbreviations

| | |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| GCM | Gross Combination Mass |
| GDG | Geometric Design Guide |
| GVM | Gross Vehicle Mass |
| LDV | Light Delivery Vehicles |
| MASH | Manual for Assessing Safety Hardware |
| NCHRP | National Co-operative Highway Research Programme |
| NMT | Non-Motorised Transport |
| RDG | Roadside Design Guide |
| RSR | Road Safety Regulator |
| SABS | South African Bureau of Standards |
| SANRAL | South African National Roads Agency |
| SANS | South African National Standards |
| SUV | Sports Utility Vehicle |
| VAB | Vehicle Arrestor Beds |

**IMPORTANT NOTE**

# 1 DESIGN PARAMETERS

## 1.1 INTRODUCTION

The design of RRS is not aimed at designing the horizontal or vertical alignment of the road. It deals exclusively with the design of the roadside. It accepts that the design aspect to avoid vehicles leaving the travel way was addressed first before considering installing RRS.

In essence, the design of RRS is to answer the questions of how to protect road users from hazards next to the road, which was discussed in Volume 1. This manual gives the standards that the RRS must comply with and the requirements that they must fulfil.

This section deals with the details of designs for different (RRS) that will fall under the proposed South African National Standards (SANS) 51317 (based on the EN 1317:1998) and the current SANS 1350: *Guardrails for roads (W-section)* standards. Some general considerations will be discussed first so that it is not repeated for every device or system.

Designs for RRS are based on parameters such as vehicle types and special requirements, speed, containment levels, angle of impact and vehicle trajectory. Consideration for the needs of motorcycles is also included.

The choice of design vehicles for RRS for South Africa was aligned with the EN 1317 as most of the vehicles on our roads are of Japanese and European origins. See Section 1.2. The heaviest cars used for tests are 1500 kg. It is recognised that there is a tendency for new vehicles to be heavier sports utility vehicles (SUV) and light trucks (colloquially known as 'bakkies') that are used as passenger vehicles, especially in double-cab configurations. The United States of America, in its Manual for Assessing Safety Hardware (MASH): 2015 standard, adopted a 2273 kg (up from 2000 kg) light truck, in line with the high sales volumes of bigger light trucks and deemed to be compatible with bigger SUVs. This trend must be monitored and considered in revisions of this document.

A revision of the EN 1317 may be due, and future guidance on higher containment levels may have to be contained in design notes to augment these standards and requirements.

The new Committee of Transport Officials Draft Standard Specifications for Road and Bridge Works for South African Road Authorities, Draft Standard Chapter 11: Ancillary Road Works, Section 11.4 Road Restraint Systems dated October 2020 provides some guidance and must be taken into account, and the Draft Standard Specification may have to be elaborated to incorporate the guidance of this RRS manual.

## 1.2 DESIGN VEHICLES FOR THE SOUTH AFRICAN CONDITIONS

It is proposed in these standards and requirements to limit the number of design vehicles and design considerations for containment to ensure better consistency in application and save cost in standardisation. The choice of vehicles is similar to what was selected in Europe. The full set of standards for containment levels is shown in Table 1, with the discussion under Application.

TABLE 1: CONTAINMENT LEVELS IN EN 1317

| CONTAINMENT LEVEL | | TEST (VEHICLE TYPE & MASS; SPEED; ANGLE) | APPLICATION |
|---|---|---|---|
| LOW ANGLES | T1 | TB21<br>(C1300; 80; 8) | N/A. Vehicle mass is not representative. Low angle tests apply to temporary safety barriers. Not considered for South African conditions |
| | T2 | TB22<br>(C1300; 80; 15) | N/A. Vehicle mass is not representative. Low angle tests apply to temporary safety barriers. Not considered for South African conditions |
| | T3 | TB41 + TB21<br>(SU10000; 70; 5) + (C1300; 80; 8) | Roadworks: 80 km/h on urban arterials. Heavy buses are operated in urban conditions, and containment level H2 is considered more appropriate |

| CONTAINMENT LEVEL | | TEST (VEHICLE TYPE & MASS; SPEED; ANGLE) | APPLICATION |
|---|---|---|---|
| NORMAL | | TB31<br>(C1500; 80; 20) | Roads with speeds limit ≤ 80 km/h, except where heavy vehicle risk has been identified. **Selected for South African conditions** |
| | N2 | TB32 + TB11<br>(C1500; 110; 20)<br>(C900; 100; 20) | Roads with speed limits > 80 km/h, except locations where heavy vehicle risk has been identified. **Selected for South African conditions** |
| HIGH | H1 | TB42 + TB11<br>(SU 10000; 70; 15)<br>(C900; 100; 20) | Roads with speed limits < 80 km / h at locations where truck risk has been identified, but articulated trucks are not expected |
| | H2 | TB51 + TB11<br>(Bus13000; 70; 20)<br>(C900; 100; 20) | Special applications at locations where heavy buses have been identified as dominant design vehicle. **Selected for South African conditions** |
| | H3 | TB61 + TB11<br>(SU16000; 80; 20)<br>(C900; 100; 20) | Locations where truck risk has been identified and where large articulated trucks are not expected |
| VERY HIGH | H4a | TB71 + TB11<br>(SU30000; 65; 20)<br>(C900; 100; 20) | Special applications at locations where 30t rigid heavy vehicle type is dominant |
| | H4b | TB81 + TB11<br>(Art38000; 65; 20)<br>(C900; 100; 20) | Locations where heavy truck risk has been identified, e.g. bridge piers. The maximum gross vehicle mass (GVM) in South Africa is 56000 kg. **Selected for South African conditions** |

The selected containment levels are shown in Table 2.

TABLE 2: CONTAINMENT LEVELS SELECTED FOR SOUTH AFRICAN CONDITIONS

| LEVEL | DESCRIPTION |
|---|---|
| N1 | Normal containment 1: Light vehicle for urban conditions: 1500 kg vehicle at 80 km/h and 20 degrees angle |
| N2 | Normal containment 2: Light vehicle for rural conditions: 1500 kg vehicle at 110 km/h and 20 degrees angle |
| H2 | High containment for heavy buses: 13000 kg at 70 km/h and 20 degrees angle. Selected routes where buses operate |
| H4b | Very high containment for heavy vehicles for all conditions except bridge parapets: 38000 kg at 65 km/h at 20 degrees angle. This is the highest containment level that is tested and may not be adequate for 56000 kg articulated interlink trucks |

The 13000 kg bus in the EN 1317 is lighter that the typcal 65 seater buses used extensively in South Africa. These buses have a GVM of 18000 kg, consisting of the tare of 10500 and load of 7500 kg. This is a limitation, and if the bus volumes and traffic composition (heavy vehicle volumes) justify the higher containment level H4b can be considered.

## 1.3 ANGLE OF IMPACT

The angle of impact for design should be within the range used in the applicable EN 1317 test. The typical angle of impact is 20 degrees. Lower angles are used in temporary road works areas where vehicles are assumed to drive closer to the barriers. These lower angles often do not occur on construction works and the H2 and H4b containment levels can be applied.

If the initial design conditions could lead to higher angles of impact, the design must be reviewed, or if not possible, the RRS must be upgraded to concrete barriers or impact attenuators that can accommodate wider angles of impact. The effect of redirecting vehicles into the adjacent lanes must be considered if a wider angle of impact will result from the geometry of the road. Vehicles can also pocket into the flexible and semi-rigid barriers.

## 1.4 VEHICLE TRAJECTORY

Vehicles hitting longitudinal barriers should preferably be redirected along the barrier. This is typical with flexible and semi-rigid RRS. Concrete barriers can redirect vehicles by reflecting them back. Where vehicles are redirected into the lane(s) from where they came, care must be taken in the design to manage possible interaction with other traffic. The post-crash vehicle trajectory must be determined, and the area where debris may be deposited must be designed not to create secondary hazards. This can be achieved by setting back the RRS from the edge of the road as far as practically possible.

Flexible and semi-flexible RRS on the inside of sharp curves cannot develop tension as the barriers deflect inwards and the vehicle is pocketed with resistance only provided by the posts collapsing or breaking.

## 1.5 MOTORCYCLES

Motorcycle crashes into RRS have not been identified as problematic on existing routes in South Africa due to low volumes of motorcycle traffic. Instances of crashes into temporary RRS on construction sites are recorded where the impact with RRS resulted in high severity of the motorcycle crashes, however, the RRS may prevent entry into the work zone where more hazardous conditions may exist.

Designing RRS for motorcycles has been pioneered in Europe. Research has indicated that the most severe hazard caused by barriers is the posts, where the motorcycle rider skids below the barrier level and hits the post, acting as a fixed object. The solution was RRS with apron beams below the normal structural beams that allow the fallen rider to skid along the road.

It is proposed that the designer evaluate the traffic composition and determine the need for motorcycle protection. Such routes are often rural mountainous terrain frequented by recreational riders. The crashes are mostly related to curves where the riders lose control and either skid following a low side slide or vault over the barrier following a high side loss of control. A second W-beam can be mounted below the normal beam.

The design should be checked against a risk analysis and economic evaluation.

## 1.6 PEDESTRIANS AND CYCLISTS AS DESIGN UNITS

Non-motorised transport (NMT) is important in urban areas and in rural settlements next to major roads. Pedestrians are problematic where they cross at random or where school sites attract many young and inexperienced pedestrians to cross in peak periods. RRS can be used to channel pedestrians to safe crossings. These RRS may not need to have a structural significance such as required for a pedestrian bridge parapet but must be strong enough to resist vandalism.

Cyclists are often most problematic along the roads, especially if there are no or narrow shoulders and no provision for cycle lanes parallel to the major roads. RRS can separate cyclists from traffic where cycle paths are provided, but bollards are advisable. Due to the height of a cyclist, bicycle barriers are 1200 mm high.

Where pedestrians are contained from falls or encroachments: Handrails to be designed for a 4.5 kN/m loading as defined in TMH 7. See also the South African National Roads Agency Ltd (SANRAL) standard drawing TD-S-P-804-V1, Figure 1.

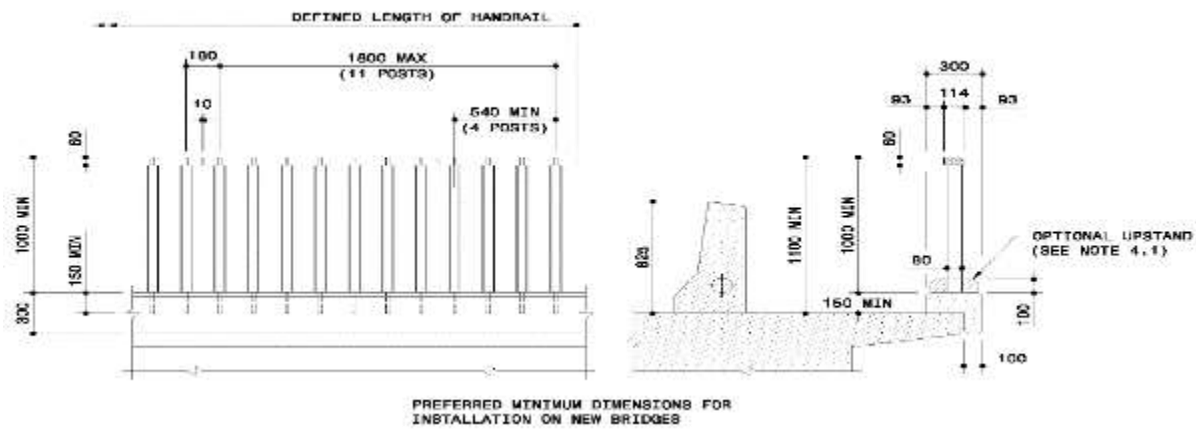



Figure 1: SANRAL Typical Detail of Handrail

## 1.7 DESIGN SPEED

The design speed of rural roads and freeways can be higher than the test conditions for containment levels (eg. 110 km/h for N2). A difference of 10 km/h is not considered significant.

Trucks have a general speed limit of 80 km/h, while the test speeds for containment levels H2 and H4b are 70 and 65 km/h, respectively. Experience with F-shape concrete barriers on freeways indicates that the barriers can withstand most impacts.

## 1.8 CLEAR ZONE

A forgiving roadside reduces the consequences for vehicles' occupants of a run-off-road. The roadside area's safety can be maximised by providing a clear area where vehicles can slow down without hitting a fixed object, allowing the driver time to regain control. This recovery area can be significant; the concept of a clear zone was developed to define an area that reflects the probability of a severe crash occurring at a site. The clear zone concept and principles provide a risk management approach to prioritise the treatment of roadside hazards at different locations. The clear zone distance provides a balance between a sufficient recovery area for errant vehicles, the cost of providing this area, and the probability of an errant vehicle encountering a roadside hazard.

The clear zone width is dependent on:

- Speed;
- Traffic volumes;
- Side slopes; and
- Horizontal geometry.

The roadside recovery zone is demonstrated in Figure 2.

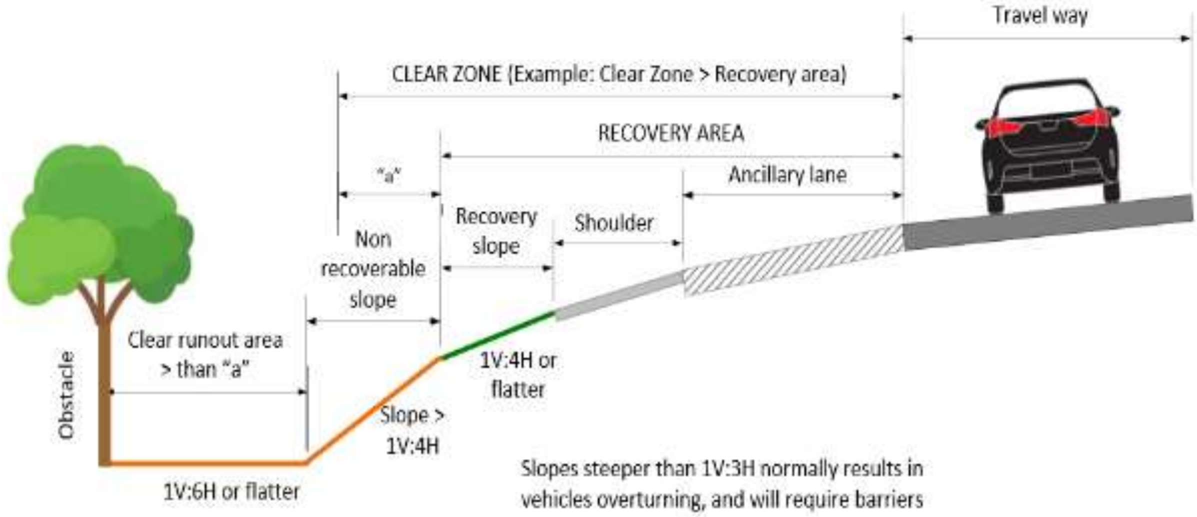



Figure 2: Roadside Recovery Zone

Table 3 indicates the appropriate width of a clear zone on a straight section of road, measured in metres from the edge of the lane, according to design speed, traffic volumes and cut or fill slope values. Where side slopes are steeper than 1:4 (i.e.non-trafficable), designers should consider providing a protective barrier. However, it is noted that the values apply to cars and that a safe roadside design for trucks would require much flatter slopes as follows:

- 1:10 is recoverable for trucks;
- 1:6 is traversable for trucks;
- 1:4 cannot be safely traversed by trucks;
- 1:6 is recoverable for cars;
- 1:4 is traversable for cars; and

- ≥ 1:3 cannot be safely traversed by cars.

For sections of road with horizontal curvature, these distances should be increased on the outside of curves by a factor that depends on the curve's operating speed and radius. Figure 3 provides guidelines on adjustment factors for clear zones on the outside of curves

| Design speed | ADT | FILL SLOPES | | CUT SLOPES | |
|---|---|---|---|---|---|
| | | 1:4 to 1:5 | 1:6 or flatter | 1:4 to 1:5 | 1:6 or flatter |
| <60 km/h | <750 | 2.0 - 3.0 | 2.0 - 3.0 | 2.0 - 3.0 | 2.0 - 3.0 |
| | 750- 1500 | 3.5 - 4.5 | 3.0 - 3.5 | 3.0 - 3.5 | 3.0 - 3.5 |
| | 1500 - 6000 | 4.5 - 5.0 | 3.5 - 4.5 | 3.5 - 4.5 | 3.5 - 4.5 |
| | >6000 | 5.0 - 5.5 | 4.5 - 5.0 | 4.5 - 5.0 | 4.5 - 5.0 |
| 70 - 80 km/h | <750 | 3.5 - 4.5 | 3.0 - 3.5 | 2.5 - 3.0 | 3.0 - 3.5 |
| | 750- 1500 | 5.0 - 6.0 | 4.5 - 5.0 | 3.5 - 4.5 | 4.5 - 5.0 |
| | 1500 - 6000 | 6.0 - 7.5 | 5.0 - 5.5 | 4.5 -5.0 | 5.0 - 5.5 |
| | >6000 | 7.5 - 8.5 | 6.0 - 6.5 | 5.5 - 6.0 | 6.0 - 6.5 |
| 90 km/h | <750 | 4.5 - 5.5 | 3.5 - 4.5 | 3.0 - 3.5 | 3.0 - 3.5 |
| | 750- 1500 | 6.0 - 7.5 | 5.0 - 5.5 | 4.5 - 5.0 | 5.0 - 5.5 |
| | 1500 - 6000 | 7.5 - 8.5 | 6.0 - 6.5 | 5.0 - 5.5 | 6.0 - 6.5 |
| | >6000 | 8.5 - 10.0 | 6.5 - 7.5 | 6.0 - 6.5 | 6.5 - 7.5 |
| 100 km/h | <750 | 6.0 - 7.5 | 5.0 - 5.5 | 3.5 - 4.5 | 4.5 - 5.0 |
| | 750- 1500 | 8.0 - 10.0 | 6.0 - 7.5 | 5.0 - 5.5 | 6.0 - 6.5 |
| | 1500 - 6000 | 10.0 - 11.5 | 8.0 - 9.0 | 5.5 - 6.5 | 7.5 - 8.0 |
| | >6000 | 11.5 - 13.5 | 9.0 - 10.0 | 7.5 - 8.0 | 8.0 - 8.5 |
| >110 km/h | <750 | 6.0 - 8.0 | 5.5 - 6.0 | 4.5 - 5.0 | 4.5 - 4.9 |
| | 750- 1500 | 8.5 - 10.5 | 7.5 - 8.0 | 5.5 - 6.5 | 6.0 - 6.5 |
| | 1500 - 6000 | 10.5 - 13.0 | 8.5 - 9.5 | 6.5 - 7.5 | 8.0 - 8.5 |
| | >6000 | 13.0 - 14.0 | 9.5 - 10.5 | 7.5 - 9.0 | 8.5 - 9.0 |

TABLE 3: TYPICAL CLEAR ZONES

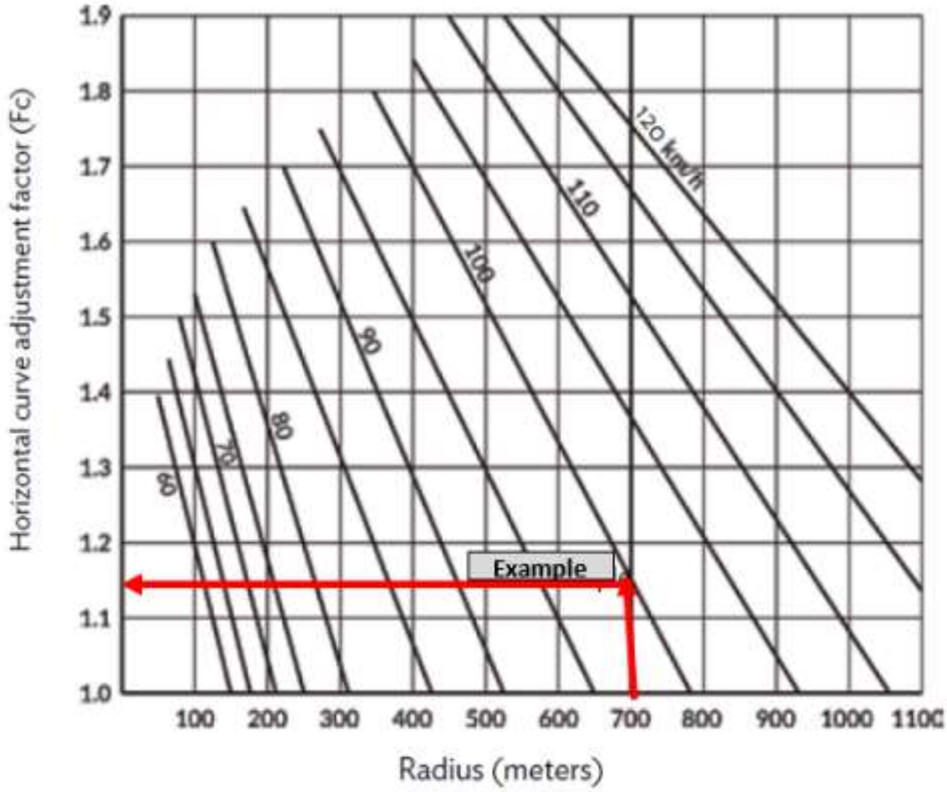



Figure 3: Clear Zone Adjustment Factors for Curves

**Example of clear zone on curve:**

**Curve = 700 m**

**Speed limit = 100 km/h**

**Fill = slope >1:4**

**ADT = 5000**

**Clear zone = 10 (Table 1) x1.15 (Fig 3)**

**(rounded to the nearest metre)**

Procedures for calculating the clear zone as stipulated in the Roadside Design Guide (RDG) are outlined in the two steps explained below:

- On shouldered roads, rigid objects shall be placed no closer to the travelled way than the clear zone distance derived by using Table 3 clear zone distances. The methods described in the current edition of the RDG, American Association of State Highway and Transportation Officials (AASHTO), may be used. A traffic barrier shall protect all hazards within the clear zone. In lieu of barriers, hazards may be constructed flush with the surface; and
- On kerbed roads with:
    - Sidewalk contiguous with kerb, rigid objects shall be placed behind the sidewalk;
    - Separated sidewalk, rigid objects shall be no closer than two feet from the back of the kerb; or
    - No sidewalk, rigid objects shall be no closer than two feet from the back of the kerb.

The design engineer shall use the clear zone requirements for a shouldered road with a speed limit greater than 40 m/h (68 km/h). Speed limit 40 m/h or less—the clear zone distance is 600 mm behind the face of the kerb.

# 2 BARRIERS

## 2.1 INTRODUCTION

Traffic barriers are systems utilised to shield road users from man-made and natural hazards alongside the travelled way. The role of a traffic barrier is dual and often conflicting.

It should be able to redirect or contain:

- An errant vehicle without imposing intolerant vehicle occupant forces;
- A range of vehicle sizes, weights and designs; and
- An errant vehicle for a range of impact speeds and impact angles (7).

Traffic barriers should conform to the following safety criteria:

- It should be able to have sufficient strength and stability to absorb the impacting energy of an errant vehicle;
- It should redirect a vehicle parallel to traffic flow to prevent secondary collisions;
- It should reduce the severity of injuries by reducing the impact forces on occupants;
- During impact, it should suffer as little as possible damage and cause as little as possible damage to the impacting vehicle; and
- It should keep an impacting vehicle upright during and after impact. It should not cause any debris or fragments that could penetrate or potentially penetrate the passenger compartment or cause danger to other vehicles travelling on the roadway.

The criteria for selecting a traffic barrier system are set out in Table 4.

TABLE 4: CRITERIA FOR RRS

| CRITERIA | COMMENTS |
|---|---|
| 1. Performance capability | The traffic barrier system should be structurally able to<br>• Contain the design vehicle; and<br>• Redirect the design vehicle. |
| 2. Deflection | The available room to deflect should not be less than the expected traffic barrier deflection. (Refer to working width of barier, Item 2.3) |
| 3. Site conditions | Conditions influencing the barrier type choice include:<br>• Slope approaching; and<br>• Distance from traffic lane. |
| 4. Compatibility | The system should be compatible with adjacent systems (like bridge railings) and end-treatments. |
| 5. Cost | The full life cycle cost should be considered in the economic evaluation of alternative systems. A system with a relatively low installation cost typically requires significantly more maintenance following impacts. |
| 6. Maintenance | |
| 6.a. Routine | Routine maintenance for W-guardrail systems for example, included checking of bolts, posts and soil stability. |
| 6.b. Collision | Flexible and semi-flexible systems require in general significantly more maintenance than rigid systems. |
| 6.c. Materials storage | Storage includes inventory items and storage space. |
| 6.d. Simplicity | Simpler designs are more likely to be installed correctly by field personnel. |
| 7. Field experience | Existing systems should be monitored in terms of performance and maintenance requirements to identify problems that can be reduced or eliminated by the use of a different barrier system. |

The common feature of longitudinal barriers is that they redirect or bounce vehicles parallel to the roadway.

This section will look at the three basic types of longitudinal barriers: flexible, semi-rigid and rigid, and the associated elements of transitions and terminals.

For all the types, identical design vehicles will be selected to limit the choices to be made. These vehicles are appropriate for South African road traffic. The EN 1317 test procedures allow for the vehicle mass, speed and angle combinations for low, normal, high and very high containment levels (see Tables 5 and 6). For this design manual, the choices for containment will be limited to normal for car (N1 urban and N2 rural), high for buses (H2) and very high for trucks (H4b).

## 2.2 CONTAINMENT LEVELS

TABLE 5: CONTAINMENT LEVEL AND TESTS

| CONTAINMENT | LEVEL | TESTS |
|---|---|---|
| Low angle | T1 | TB 21 |
| | T2 | TB 22 |
| | T3 | TB 41 + TB 21 |
| Normal | N1 | TB 31 |
| | N2 | TB 32 + TB 11 |
| High | H1 | TB 42 + TB 11 |
| | H2 | TB 51 + TB 11 |
| | H3 | TB 61 + TB 11 |
| Very High | H4a | TB 71 + TB 11 |
| | H4b | TB 81 + TB 11 |

TABLE 6: TEST NUMBERS FOR VEHICLE MASS, SPEED AND ANGLE

| TEST | TYPE OF VEHICLE | MASS (kg) | SPEED (km/h) | ANGLE (°) |
|---|---|---|---|---|
| TB 11 | Car | 900 | 100 | 20 |
| TB 21 | Car | 1300 | 80 | 8 |
| TB22 | Car | 1300 | 80 | 15 |
| TB31 | Car | 1500 | 80 | 20 |
| TB32 | Car | 1500 | 110 | 20 |
| TB 41 | Rigid Truck | 10000 | 70 | 5 |
| TB 42 | Rigid Truck | 10000 | 70 | 15 |
| TB 51 | Bus | 13000 | 70 | 20 |
| TB 61 | Rigid Truck | 16000 | 80 | 20 |
| TB 71 | Rigid Truck | 30000 | 65 | 20 |
| TB 81 | Articulated Truck | 38000 | 65 | 20 |

For the typical car vehicle, test TB31 (Table 5 and 6) is selected for urban and low-speed applications and test TB32 for rural and high-speed applications. The 1500 kg vehicle represents the modern sedan car, and smaller cars will be covered. SUV and double-cab light delivery vehicles (LDV) or light trucks (up to 2273 kg) are not yet covered by EN 1317(or MASH).

For the typical bus, test TB51 is the only test. At 13000 kg, it is lighter than a South African bus, at a GVM of 17 090 kg for a two-axle bus per National Road Traffic Act Regulation 240 (b) (ii) and (c) (iv). The test speed is 70 km/h, which is low for rural bus operations. The bus option will be used on selected high volume bus routes with low heavy truck volumes.

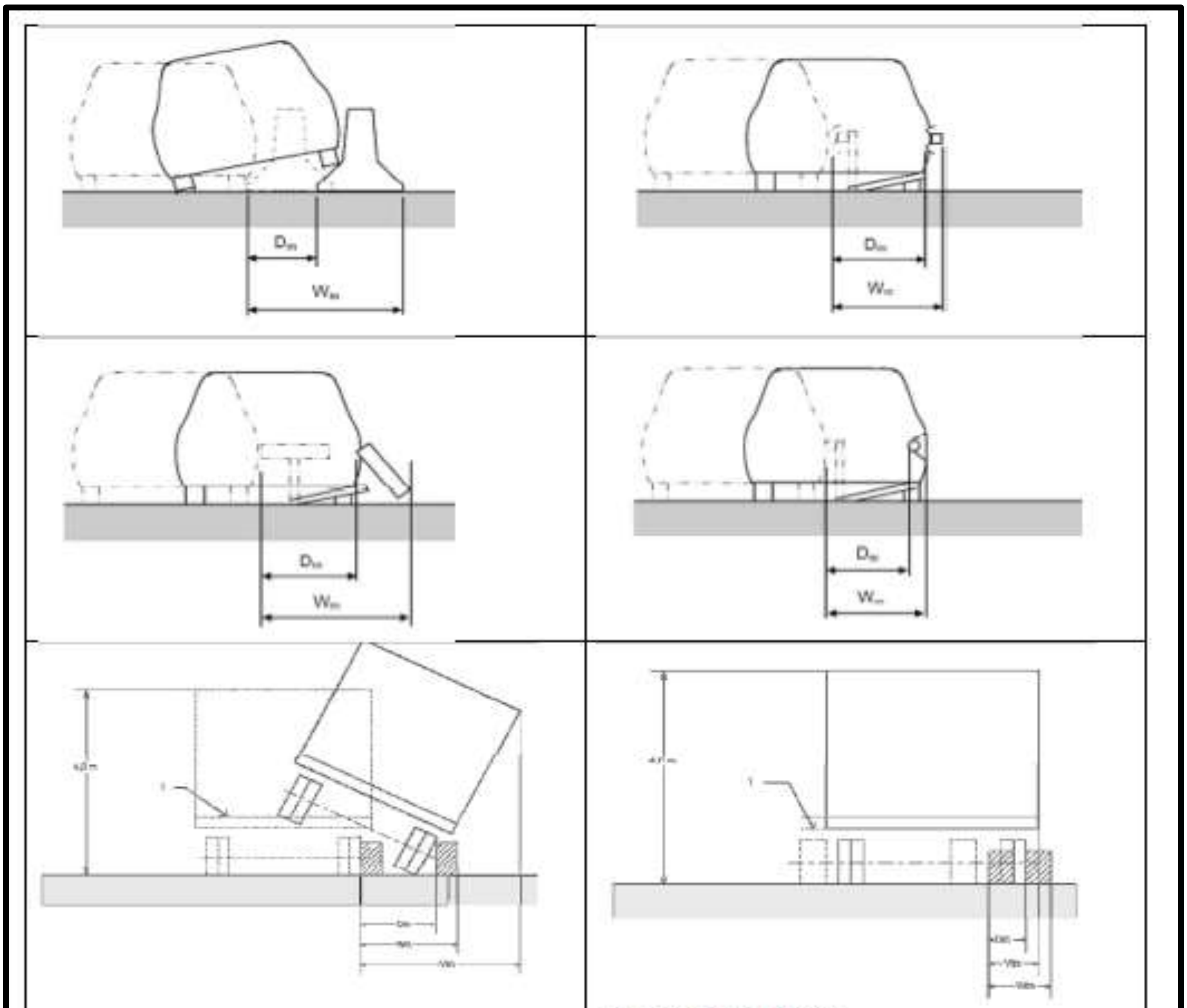
Containment level H4b will be used for routes where trucks are the main design vehicle. EN 1317 evaluate the typical truck at 38000 kg and 65 km/h. The mass is close to the general European Gross Combination Mass (GCM) of 40 t, but several countries have different GCM limits such as 44 t in Belgiu Great Britain and Italy, 48 t in Denmark, 50 t in Norway and the Netherlands, 60 t in Sweden and Finland. In South Africa, the GVM is 56 t. The risk and economic analysis of truck RRS are important and may point towards rigid barriers to contain the truck's significantly higher mass and speed on long freight trips. Bridge parapets are considered a policy issue based on structural design parameters.

## 2.3 WORKING WIDTHS AND INTRUSIONS

Working width contains three sub-elements.

- Dynamic deflection – the largest transverse deflection of any part of a road safety barrier system, typically measured from the inner edge;
- System width – the width of the system (barrier) during or after impact and including any deformation; and
- Vehicle intrusion or vehicle roll allowance – is the lateral distance a vehicle protrudes beyond the deflected barrier.

The definitions are illustrated in Figure 4.



(Source: IS EN 1317-2)

Therefore, the working width is the maximum lateral distance between any part of the barrier on the undeformed traffic side and the maximum dynamic position of any part of the barrier of the vehicle body. Working width classes as defined in EN 1317 are shown in Table 7.

TABLE 7: CLASS OF WORKING WIDTH

| CLASS OF WORKING WIDTH | LEVEL OF WORKING WIDTH |
|---|---|
| W1 | ≤ 0.6 m |
| W2 | ≤ 0.8 m |
| W3 | ≤ 1.0 m |
| W4 | ≤ 1.3 m |
| W5 | ≤ 1.7 m |
| W6 | ≤ 2.1 m |
| W7 | ≤ 2.5 m |
| W8 | ≤ 3.6 m |

The working width will be determined by the location, fixed objects behind and function of the RRS. The range of available products may dictate the typical working widths used in the design. It is normally more economical to design for a range of commercially available products without designing for a specific product.

For longitudinal barriers with no fixed objects behind and for wide medians, the working width can be < 2.1 m (W6). This can be extended for flexible barriers to 3.5 m (W8) where the space is available and flexible barriers are appropriate. See Figure 5 for an example of inadequate working width.

Working width can be reduced by using the same rail with closer posts, stronger posts, or a rail at the back (double rail configuration). If working width cannot be provided near a local fixed object, the RRS must be rigid such as concrete with no working width, with appropriate transitions to semi-rigid RRS at the ends.

Figure 5 shows inadequate working width to the lamp post. The beam sections are also too short to develop tension and may fall over. (A vehicle hitting the barrier will push it over and hit the lamp post). Also note that the sign gantry is not protected. In cases where the fixed objects are close enough to each other that the ends are within 50 m from each other with the transitions and terminals, the barrier must be made continuous. Also, see Section 2.8.

Figure 5: Short Barrier Section – Length of Barrier Insufficient and Very Narrow Working Width to Lamp Post

Bridge parapets are rigid and have no working width. The transitions on either side to semi-rigid rails must be done to standard details or using a tested RRS. The current SANRAL detail shows poles at the midpoint of the typical 3.81 m barrier with a second beam at the rear in the transition.

The vehicle intrusion or vehicle rollover of the heavy goods vehicle is its maximum dynamic lateral position from the undeformed traffic side of the barrier. The class and level of vehicle intrusion as defined in EN 1317 is shown in Table 8. It will be noted that with a maximum heavy vehicle height of 4.3 m, the higher classes of intrusion can imply the vehicle had overturned. Vehicle intrusion is important on curves with fixed objects or retaining walls on the outside of the barrier.

TABLE 8: CLASS OF INTRUSION

| CLASS OF VEHICLE INTRUSION | LEVEL OF VEHICLE INTRUSION |
|---|---|
| VI1 | ≤0.6 m |
| VI2 | ≤0.8 m |
| VI3 | ≤1.0 m |
| VI4 | ≤1.3 m |
| VI5 | ≤1.7 m |
| VI6 | ≤2.1 m |
| VI7 | ≤2.5 m |
| VI8 | ≤3.5 m |
| VI9 | >3.5 m |

## 2.4 SITE CONDITIONS

Site conditions play a significant role in selecting appropriate barriers. The slope approaching a flexible barrier should, for example, not exceed 10%, while rigid barriers should not be used where the expected impact angle is large. Narrow fill sections could result in conditions where post spacing and post support cannot perform as intended. Several site-specific aspects will majorly influence selecting a particular type of barrier to meet the performance requirements at that location.

These aspects include the following:

- Available longitudinal space;
- Available lateral width;
- Hazardous site length;
- Hazard width and height;
- The proximity of hazard to the traffic;
- Available maintenance space;
- Surface conditions and anchoring options;
- Probable impact speed and impact angle;
- Average traffic volume and traffic mix;
- Expected impact frequency; and
- Unidirectional or bi-directional traffic.

## 2.5 GROUND CONDITIONS

Most safety barrier systems rely on certain ground conditions to function satisfactorily.

The setback is the dimension between the traffic face of the safety barrier and the edge of the road pavement. It should be noted that the road pavement includes any hard shoulder or rigid strip.

The setback dimensions proposed are as follows:

- The minimum setback on a verge shall be 1.2 m. This may be reduced to 0.6 m if a rigid strip with a width of 1m or more or hard shoulder is present or where the road design speed is 85 km/h or less;
- The minimum setback shall be 0 m (zero) at central reserves, where a hard strip of width 0.6 m or greater is present. If there is no hard strip present, the minimum setback shall be 0.6 m; and
- The performance of the safety barrier system must not be compromised by the presence of a filter drain, cables or the like close to the barrier foundations. The clear distance required between the barrier and any feature which may affect the safety barrier performance shall be ascertained.

## 2.6 LATERAL POSITIONING

For typical containment barriers (N2), the working width should be W6 **(**2.1 m) where space is available. However, the setback should also be as large as practicable to provide the maximum width in which errant vehicles can regain control. Within the limited verge or central reserve widths available with many road cross-sections, it will be necessary to provide a reasonable compromise between a large working width and a generous setback. It must also be ensured that the detailing of the drainage and services within the verge does not restrict the selection of safety barriers unduly.

Design decisions regarding the lateral position of the barrier and its working width are further complicated by factors such as the barrier setback required to achieve the required stopping sight distance. In some cases, additional verge width may need to accommodate a higher working width barrier or a larger setback.

For isolated hazards, the safety barrier should be placed as close to the obstruction as possible, and hence a small working width (normally **W2** to **W4**) should be selected. This provides the maximum available setback and maximises the space available for the errant vehicle to be brought under control.

For high containment barriers with small working widths, keeping the setback distance as small as possible will minimise the angle of impact and reduce the severity of impact on the occupants of the errant vehicle.

Where combinations of hazards are to be protected by a single length of safety barrier, the setback of the barrier should be established by assessing the obstruction nearest to the road as if this was an isolated hazard. This setback should be retained for the remaining obstructions, although the working width can be varied to suit each obstruction. However, changes in working width along the length of a barrier are subject to suitable transitions being available.

Except for the bridge and sign gantry supports in central reserves containing in situ concrete barriers, where objects are being protected, the working width of the safety barrier must be such that under design conditions, the hazard is not impacted. There must also be full headroom for the impact vehicle in its position of maximum lateral displacement.

On verges, the working width of the safety barrier shall not allow the traffic face of the barrier, when deflected to the full working width, to extend beyond the intersection of the embankment or cut slope and the verge.

On central reserves, the safety barrier position and working width shall be such that no part will deflect into the opposing traffic lane under design impact conditions. On wide central reserves with anti-dazzle hedges, the centre of the safety barrier should, where practicable, be at least 2.4 m from the centre of the hedge.

## 2.7 LENGTH OF NEED

The determination of the length of need is common for all systems. This can be determined from the following diagrams in Figures 6 and 7.

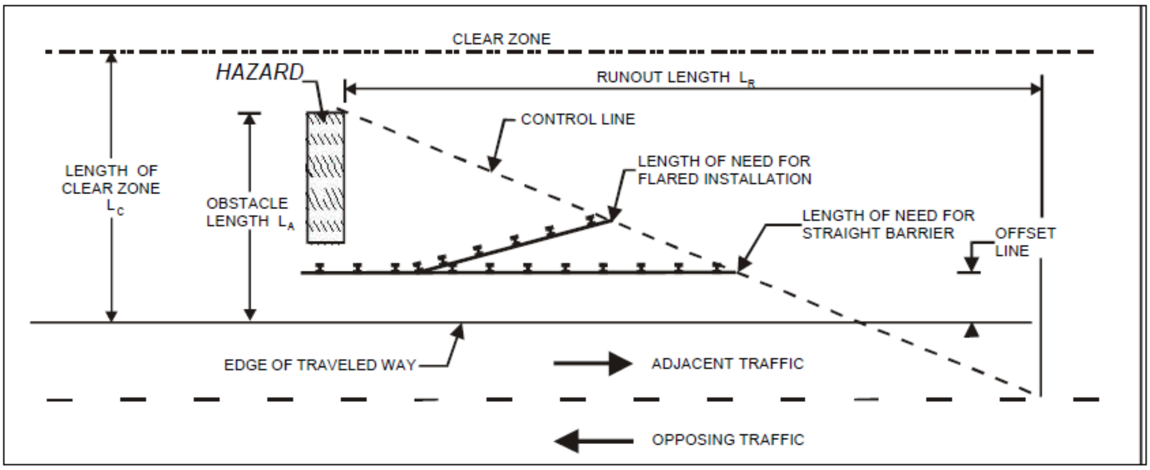



Figure 6: Length of Need from an Adjacent Lane

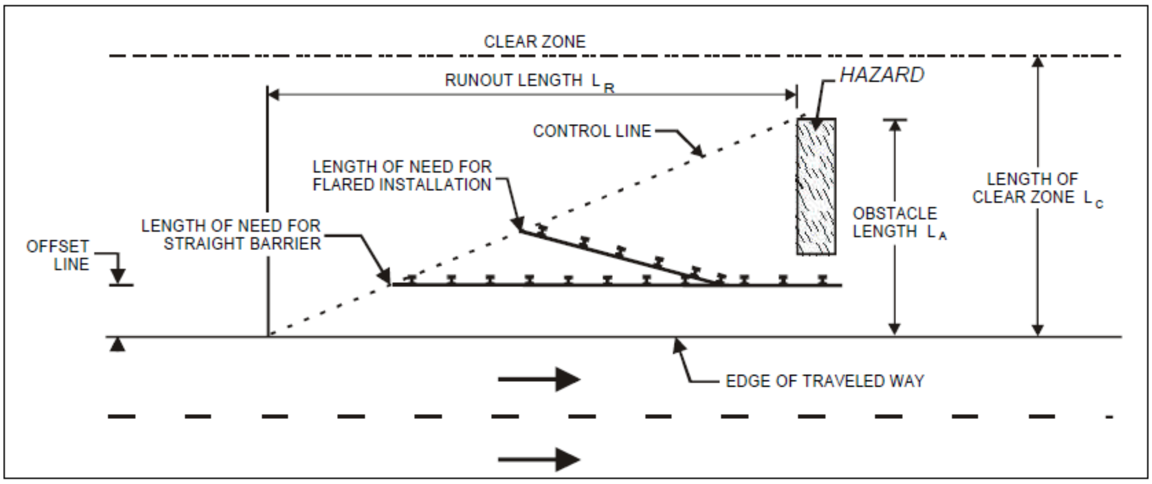



Figure 7: Length of Need from the Opposite Lane

The runout length used in the above figures can be obtained from Table 9. Note that the runout length is based on vehicle movement and economic evaluation, including risk and crash costs. See Figure 8 for an inadequate length of need on approach to a high fill.

Figure 8: Illustration of Inadequate Working Width and Length of Need

TABLE 9: DESIGN SPEED AND RUNOUT LENGTH

| DESIGN SPEED km/h | RUNOUT LENGTH (m) | | | |
|---|---|---|---|---|
| | ADT <800 | 800<ADT<2000 | 2000<ADT<6000 | ADT>6000 |
| 50 | 40 | 45 | 50 | 50 |
| 60 | 50 | 55 | 60 | 70 |
| 80 | 75 | 80 | 90 | 100 |
| 100 | 100 | 105 | 120 | 130 |
| 110 | 110 | 120 | 135 | 145 |

The length of need for a narrow-fixed object such as a gantry post will be taken as 20 m on either side, based on the vehicle's footprint of typical width and the angle of impact.

## 2.8 GAPS BETWEEN RRS SECTIONS

Gaps of 50 m or less should be closed to avoid the proliferation of more hazardous terminal sections. The number of approach terminal sections must be minimised. Gaps larger than 50 m and up to 100 m must be considered for closure unless there is a specific reason to accommodate a gap.

## 2.9 HEIGHT OF SAFETY BARRIER

Safety barriers shall be set at the height specified for the system, within the specified tolerances. Following resurfacing or overlay works, particular care shall be taken to ensure that the barrier is at the correct height. Barriers that are too high may allow vehicles to underrun, and too low may cause vehicles to vault over.

Where the setback is less than 1.5 m, the height of the barriers shall be related to the edge of the road pavement. Elsewhere, the height shall be measured from the general ground level near the front of the barrier.

## 2.10 KERBS

Road kerbs are an important element of road section that serve a number of purposes as given below:

- Retaining the carriageway edge to prevent 'spreading' and loss of structural integrity;
- Acting as a barrier or demarcation between road traffic and pedestrians or verges;
- Providing physical ‘check’ to prevent vehicles leaving the carriageway; and
- Forming a channel along which surface water can be drained.

There are many different types of road kerbs used globally. Fifty years ago, natural stone, such as granite, was the most popular, but these have now been supplanted by precast concrete. Other than those with a square profile, all kerbs have what is known as a 'watermark' or a 'waterline'. This is a line on the face above which surfacing (and therefore surface water) is not normally expected to extend. The surfacing level is kept 25 mm or more below the watermark in many cases. The watermark is not a physical mark but generally coincides with a change in angle of the kerb face. Standard kerbs are produced in terms of the figures in SANS 927: 2007 Precast concrete kerbs, edgings and channels. Examples are shown in Figure 9.

In front of a safety barrier, kerbs can contribute to the vehicle overturning or ascending the safety barrier. If kerbs in front of the safety barrier cannot be avoided on roads with a design speed of 85 km/h or more, the kerbs should be splayed over the entire height by at least 45° to the vertical and not higher than 80 mm.

Kerbs are RRS in their own right in urban areas and at intersections with islands to channel vehicle streams. Islands provide traffic calming and aesthetic benefit, space to locate pedestrian safety features and traffic control devices, amenities, landscaping and stormwater management. The choice of kerb profile is often constrained by the South African Bureau of Standards (SABS) standard profiles, but there are sufficient options to select an appropriate kerb for the safe performance of the desired road restraint functions. Mountable kerbs provide strong delineation and guidance to keep vehicles on the roadway where encroachment onto the verge is of low risk. Semi-mountable kerbs provide a stronger containment to define NMT paths on the sides. Barrier kerbs can be used to separate vehicles and NMT more sharply, but the risk of vehicle destabilisation must be considered. The use at roundabouts of mountable kerbs to define the apron for heavy vehicles to ride over and high barrier kerbs to define the inner circle must be designed with care as these features can destabilise motorcycles and increase the severity of crashes.

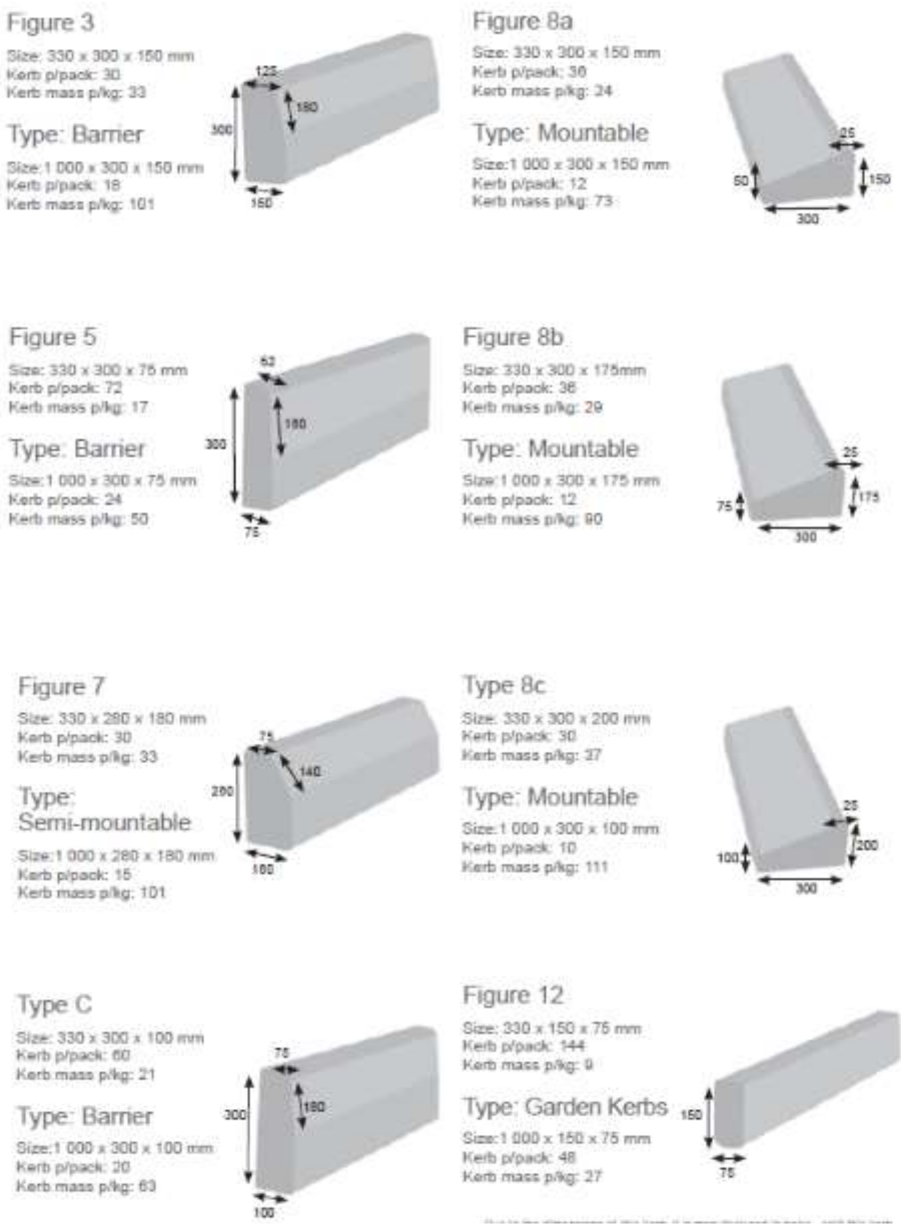



Figure 9: Typical and Standard Kerbs Used in South Africa

## 2.11 JUSTIFICATION FOR THE INSTALLATION OF BARRIERS

The manual proposes a risk assessment and an economic analysis approach to justify the need for barriers, discussed in Annexure A. The risk assessment will be determined based on an enhanced NetSafe analysis and the risk factors based on crash modification and historical crash data. The economic analysis will look at the reduction in crashes and crash severities to justify the lifecycle cost of the installation of RRS.

There, however, is a need to simplify the justification for installation where it involves standard conditions. This is referred to as policy or road authority procedural justifications. Examples are bridge parapets and protection for bridge piers in medians. This is not the same as the historical approach of warrants. Understanding historic warrants do give guidance on where guardrails are typically used before and where the risk-based approach will be used to upgrade old installations. See Figure 11.

The **SANRAL GDG** manual considers filling height and batter's slope. The manual typically applies to national roads, mainly Classes 1, 2 and 3 roads that carry significant traffic.

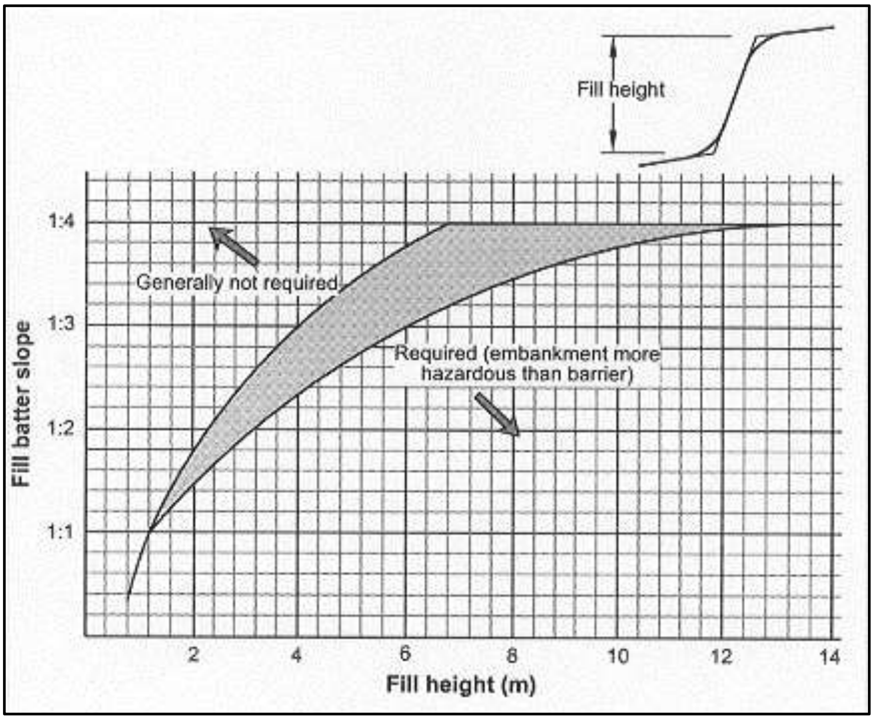
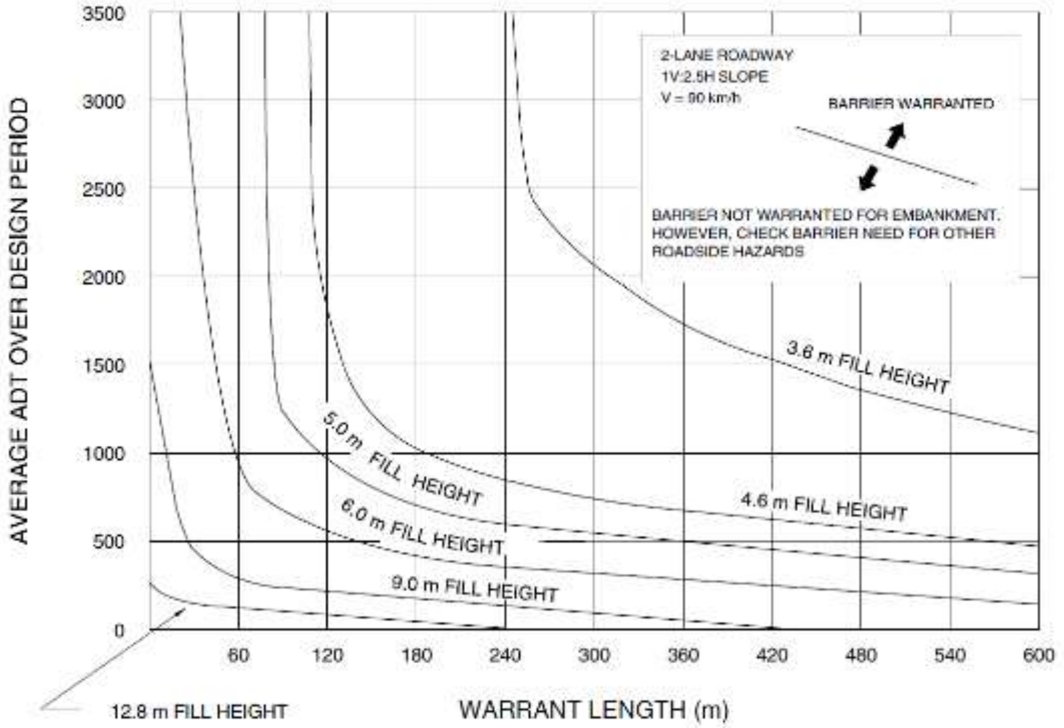


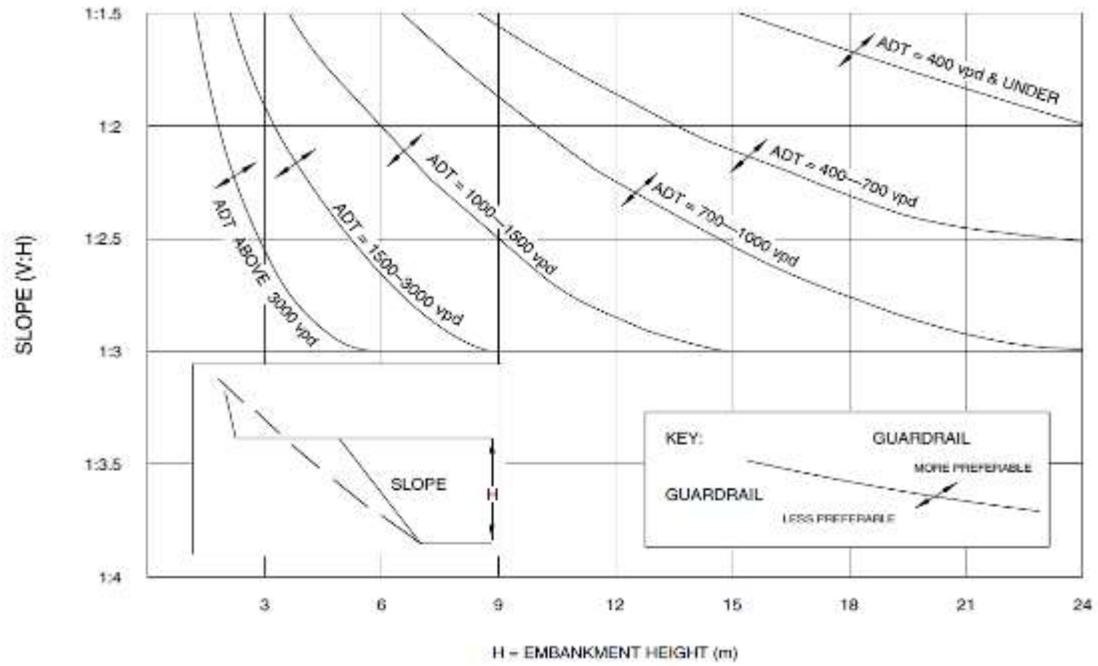

Figure 10: Warrants for the Use of Roadside Barriers

The SANRAL GDG 2003, Table 10 below, lists the typical roadside obstacles shielded with RRS.

TABLE 10: ROADSIDE OBSTACLES USUALLY CONSIDERED FOR SHIELDING

| TERRAIN OR OBSTACLE | COMMENT |
|---|---|
| Bridge piers, abutments, railing ends | Shielding analysis required |
| Boulders | Judgement: nature of object: likelihood of impact |
| Culverts, pipes (smooth) | Judgement: based on size, shape, location |
| Cut slopes (smooth) | Shielding analysis is not generally required |
| Cut slopes (rough) | Judgement: based on likelihood or impact |
| Ditches (parallel) | Analysis generally required |
| Embankments | Judgement: based on fill height and slope |
| Retaining walls | Judgement: based on wall smoothness and angle of impact |
| SOS telephones | Shielding analysis required |
| Traffic signal supports | Shielding analysis for isolated signals in the clear zone on high-speed (80 km/h or greater) facility |
| Trees | Judgement: site-specific |
| Utility poles | Judgement: case by case basis |
| Permanent bodies of water | Judgement: depth of water, the likelihood of encroachment |


2-LANE ROADWAY
1V:2.5H SLOPE
V = 90 km/h
BARRIER WARRANTED
BARRIER NOT WARRANTED FOR EMBANKMENT, HOWEVER, CHECK BARRIER NEED FOR OTHER ROADSIDE HAZARDS
3.6 m FILL HEIGHT
4.6 m FILL HEIGHT
5.0 m FILL HEIGHT
6.0 m FILL HEIGHT
9.0 m FILL HEIGHT
12.8 m FILL HEIGHT
AVERAGE ADT OVER DESIGN PERIOD
WARRANT LENGTH (m)
3500
3000
2500
2000
1500
1000
500
0
60
120
180
240
300
360
420
480
540
600


ADT = 400 vpd & UNDER
ADT = 400—700 vpd
ADT = 700—1000 vpd
ADT = 1000—1500 vpd
ADT = 1500—3000 vpd
ADT ABOVE 3000 vpd
SLOPE
H
KEY:
GUARDRAIL
MORE PREFERABLE
GUARDRAIL
LESS PREFERABLE
SLOPE (V:H)
H = EMBANKMENT HEIGHT (m)
1:1.5
1:2
1:2.5
1:3
1:3.5
1:4
3
6
9
12
15
18
21
24

## 2.12 FLEXIBLE SYSTEMS: CABLES

### 2.12.1 Introduction

When a vehicle impacts a cable system, tension develops in the cable. After sufficient tension has developed, the vehicle is redirected. At impact, the cables wrap around the bumper and front fender of the vehicle. Lateral resistance is developed as the cables, which end anchors restrain, are deflected. As they deflect and stretch, large tensile forces develop in the cables, and lateral components of those tensile forces redirect the vehicle.

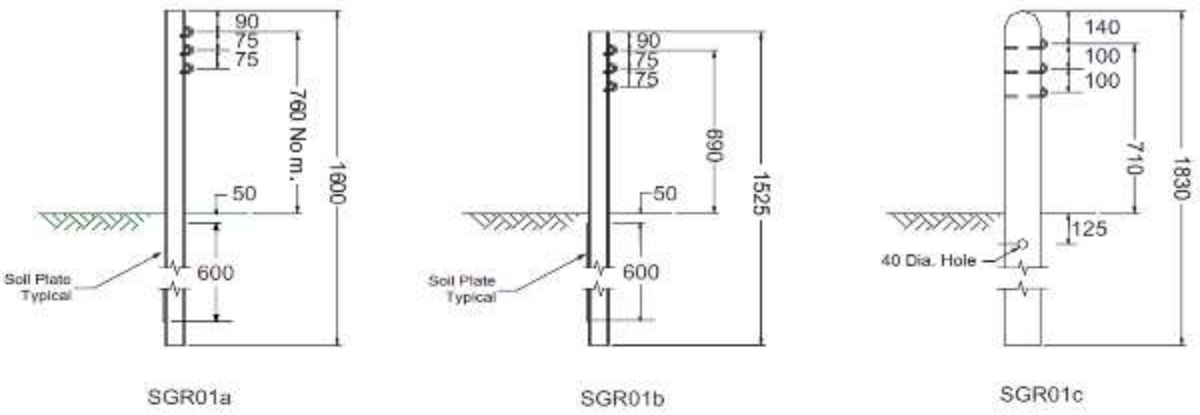
Typical application and purpose: Cable systems are typically used on freeways outside of short radius curves to redirect errant vehicles and in wide grassed medians where they also prevent cross-over crashes and illegal U-turns. See Figure 13.

Design requirements: The cable system requires the most working width of all barriers systems as it stretches the most. It is difficult to change stiffness at transitions to rigid barriers and is therefore used as a complete and isolated system. The system is not recommended inside a curve, as it is essential to work in tension. Impacts from the outside of a curved cable system will not be held back until the cable can start to stretch between the anchor terminals.

Figure 13: Illustration of Cable System

## 2.12.2 Typical Drawing of a Flexible Cable System

AASHTO Road Side Design Guide specifies the following designs for flexible cable systems, Figure 14. It is, however essential to attend to supplier specifications.




Note: All dimensions shown are in millimeters unless otherwise noted.

| AASHTO Designation | SGR01b | SGR01b | SGR01c |
|---|---|---|---|
| Post Type: | S75 x 8.5 steel | 9 kg/m steel flanged channels | 140-mm dia. modified wood |
| Post Spacing: | 5000mm | 5000mm | 3800mm |
| Beam Type: | 19-mm dia. steel cables | 19-mm dia. steel cables | 19-mm dia. steel cables |
| Maximum Dynamic Deflection: | 3.5 m | 3.5 m | 3.5 m |

Figure 14: Typical Drawing of a Flexible Cable System

### 2.12.3 Restrictions on the Use of the Cable System

The use of cable systems is not recommended on:

- Sharp curves;
- The inside of horizontal curves, as the necessary cable tension cannot develop;
- Facilities with high heavy vehicle volumes;
- At hazardous locations or high crash frequency locations as it offers no protection after being hit by a vehicle;
- Sites where adequate deflection distance cannot be provided over a clear area behind the barrier system (refer to Section 12.2.2 for more detail); and
- Any of the following roadside characteristics:
  - On slopes steeper than 1:10 to guard against vehicle vaulting;
  - On slopes steeper than 1:6 to prevent the ramping effect when a vehicle hit the barrier higher than intended;
  - Embankment slopes 1:2 and steeper; and
  - Any roadside that may cause vehicle ramping.

### 2.12.4 Containment Level

Cable barriers are indicated for containment levels N1 and N2, where site conditions and design requirements can be met. Cable systems within line anchors at short spacing have been tested for containment level H1.

### 2.12.5 Working Width and Deflection

A cable system can only be considered if adequate deflection distance over a clear roadside area exists. For roadside barriers, 3.5 m deflection distance should be provided, and for median barriers, 7.0 m deflection distance can be considered if the working width does not intrude into the opposing lanes. The barriers placed on the inside of curves require additional deflection distance to allow for adequate tension to develop. It is therefore not recommended for use on the inside of curves.

### 2.12.6 Structural Capacity

The four-strand cable was designed and tested for use by passenger vehicles. Note that the system was not developed and does not provide adequate structural capacity to contain vehicles weighing more than 2000 kg. Use of the system on heavy vehicle routes is therefore not recommended.

### 2.12.7 Installation

The cable system is sensitive to correct height installation and will not function properly if the system is not provided at the design height. Refer to suppliers'installation manual

### 2.12.8 Approach

The approach to the cable system should be relatively flat, traversable and free of any ditches or kerbs that could affect vehicle trajectory.

### 2.12.9 Maintenance

The clear deflection distance should be kept clean and free from any objects. The maintenance requirements, both in terms of collision maintenance and routine maintenance of the specific cable system design, should be determined before choosing a cable system.

Authority should be sure that:

- They would be able to report and restore cable systems that were damaged during a collision quickly enough to ensure that the cable can provide adequate protection continuously;
- The necessary materials for routine and collision maintenance are readily obtainable and affordable;
- The maintenance personnel are adequately trained to ensure proper installation and maintenance; and
- They would confirm that the system is not considered for the restrictive conditions described previously.

### 2.12.10 Quality Control

Correct installation and collision maintenance are of the utmost importance to ensure that the barrier system functions properly and safely. When a specific type of cable system is chosen, it is crucial that the specific material as used by the original developers as the use of substitutes may lead to system failure and subsequent injuries.

### 2.12.11 Terminals/End Treatment

The end treatment of a cable system is critical to enable the system to develop sufficient impact strength. The cables are anchored in a concrete block that is level with the ground and is flared down. There is a risk of vaulting.

### 2.12.12 Vehicle Types

The cable system is designed for passenger vehicles. It relies heavily upon the solid engagement of the cable with the fender and front bumper to ensure proper containment of the vehicle. Unfortunately, recent vehicles styling includes low-sloping frontal profiles to improve aerodynamics and appearance. There is a concern of vehicle under-running by these vehicles. However, the design height of the cables cannot be lowered as it will reduce the effectiveness of the system for SUVs and light trucks (LDVs).

### 2.12.13 Road Design Principles

Cross-section: The approach to a cable system should be flat, without any kerbs or ditches.

Kerbing and fixed objects: No fixed objects or kerbing should be provided in front of the cable system as it can cause vehicle vaulting and the resulting failure of the barrier system.

### 2.12.14 Advantages of the System

The four-strand cable system has the following advantages:

- Low installation cost;
- Effective passenger vehicle containment and redirection;
- More aesthetically pleasing; and
- Easy and relatively quick maintenance that requires limited stock.

The standards to which the flexible barriers must conform is per EN 1317 Part 2.

## 2.13 SEMI-RIGID SYSTEMS: STEEL PROFILES

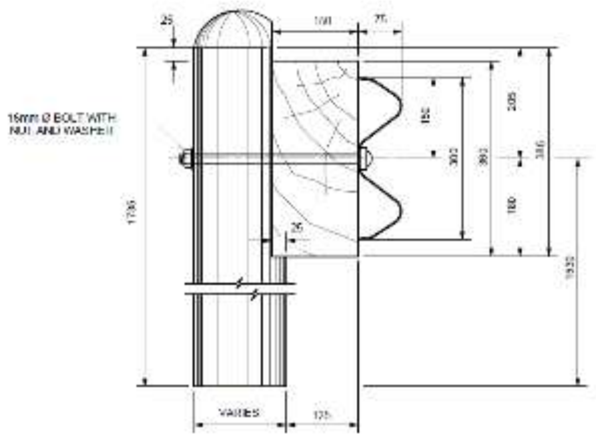
The most used RRS in South Africa is the semi-rigid system in the W-shape section. There are variations of this profile as well as round, square and rectangular box profiles, as used in Europe. The discussion will be based on the W-beam profile as this profile will continue to dominate due to familiarity of maintenance teams, stock, availability and standardisation under the existing SANS 1350.

These guardrails can be utilised under widely varying conditions. Typically, the system is used as a single guardrail beam element mounted on strong timber posts erected at 3.81 m centres. They are also used as ramped end terminals and transitions to rigid bridge parapets. In these applications, the post spacings are reduced to 1.905 m, and two guardrail beam elements are mounted on either side of the posts.  These transitions reduce the working width leading to the rigid parapet.

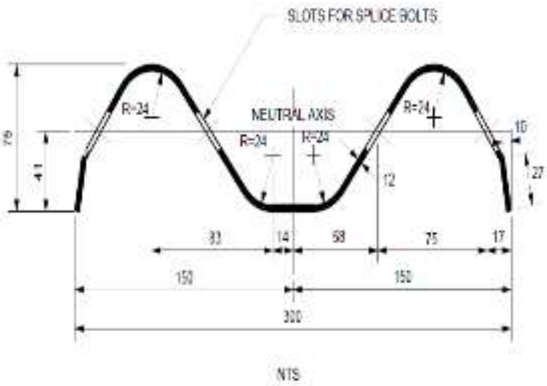
When a vehicle makes contact with a guardrail, the W-beam forms a wide tension band by bending and flattening to contain the vehicle. The posts rotate and bend to the ground line as the passive pressure of the soil fails. During the contact, a restraining force acts on the side of the vehicle. The line of action of this force is lifted and dropped as the posts and spacers deflect. By changing the direction of the force, vaulting, rollover and snagging are reduced. Further restraint for the vehicle develops as the posts yield and the metal of the barrier tears away from the bolt heads. The barrier system absorbs kinetic energy through friction, deformation, and posts' breaking.

Typical application and purpose of W-section systems as found on the South African roads are along roads were warranted to protect fixed objects or high fills.

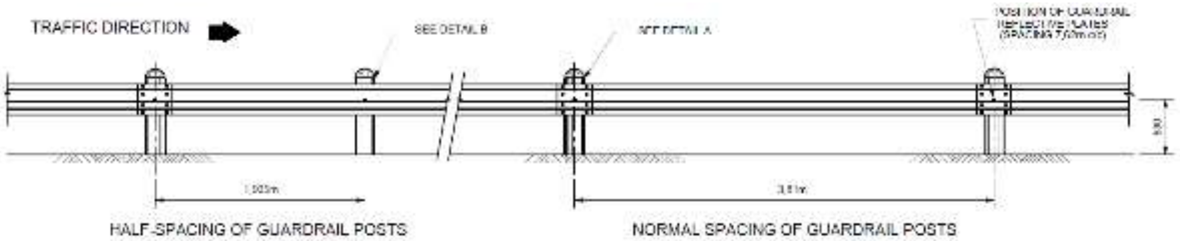
### 2.13.1 Typical Drawing of a W-Section Beam Elements



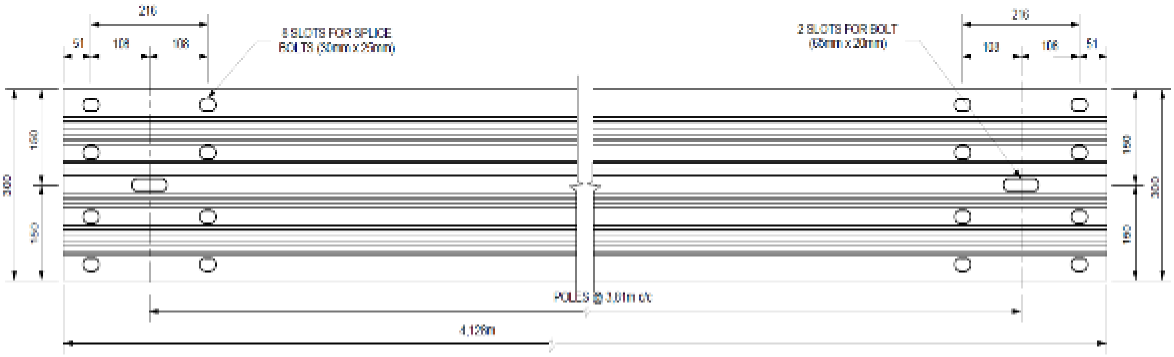

ELEVATION OF GUARDRAIL




SECTION THROUGH GUARDRAIL




SPACING OF POSTS AND POSITION OF REFLECTIVE PLATES




TYPICAL GUARDRAIL SECTION

### 2.13.2 Design Requirements for W-Section Beam Elements

W-section beam elements have been standardised in South Africa and have to comply with SABS 1350. These elements are manufactured from cold-rolled steel and hot-dip galvanised. They are connected to form a long rail utilising eight specially designed splice bolts per connection. The design of these splice connections ensures that the chances of rail failure under impact are limited as far as possible. Road authorities may specify W-beam RRS complying with SANS 1350, which is a method specification. Current procurement practice that affects the new standard specifications is based on performance: if containment level and working width are specified, the contractor may use any RRS tested to EN 1317 (or MASH) equal to or better than the specified performance. The designer must ensure that the application is comparable to the test conditions. These barriers should conform to Containment Level N2 and working width of W6.

### 2.13.3 Posts

Most guardrail installations in South Africa are done with round timber posts. See Figure 15. Timber guardrail posts need to comply with SABS 457.

These differ in size from 145 mm to 230 mm diameters by 1.2 m and 1.8 m long. It is advisable to only use the posts in the 180 mm to 230 mm ranges. The width of these posts ensures that sufficient resistance is developed to withstand the designed impact conditions, while the length of the post and the ratio of buried length to exposed length provide for the post's rotation. This results in lateral movement of the post at the surface under most impact conditions. Steel guardrail posts are seldomly used and often only in isolated cases on concrete slabs or side drains. The designer should be careful in accepting several steel posts on one section of a rail while all the other posts on both sides of such a section are timber. The deflection characteristics of the two types of posts are significantly different and have different performance under impact. Transitions between the two sets of stiffnesses must be done over an appropriate length, typically four sections.

It should be noted that the square wooden and steel posts are also used in the USA, and most of the older tests under the National Co-operative Highway Research Programme (NCHRP) 350 programme used them. According to the FHWA, there is insufficient performance information to recommend whether they may be substituted for steel or rectangular wood posts. Research by Faller et al. in 2009 showed that round poles 180 mm to 200 mm did perform to the T3 test level of NCHRP 350 and could be used as a substitute for the W 6x9 steel posts, and by inference, the rectangular wood posts.

The use of weak posts, obtained by drilling holes in the posts to allow them to break and let the RRS perform in tension was not implemented in South Africa.

Figure 15: Illustration of Post and Beam Connection

### 2.13.4 Offset Blocks

The rail elements are offset from the posts utilising offset blocks (spacer blocks complying with SABS 457). These blocks have a dual function: Firstly, they offset the rail from the post, thereby reducing the possibility of wheels snagging on the posts. Secondly, they maintain rail height when the rail is impacted and starts to rotate downward.

### 2.13.5 Connections

The post bolts connect the rail and the posts and must keep the rail in position during the deflection part of any impact. Under extreme impacts, when the posts start to rotate downwards, the rail should also separate from the posts to reduce the chances of the impacting vehicle vaulting over the rail. Under severe impacts, it would be better if the rail separates from the posts earlier.

### 2.13.6 Installation

The semi-rigid beam system must be installed to the correct height, and the location of kerbs and asphalt berms must be under or behind the face of the barrier to prevent it from listing the vehicle and engaging the beam at the wrong height.

### 2.13.7 Approach

The approach to the beam barriers should be relatively flat, traversable and free of any ditches or kerbs that could affect vehicle trajectory.

### 2.13.8 Maintenance

The clear deflection distance should be kept clean and free from any objects. The maintenance requirements, both in terms of collision maintenance and routine maintenance of the specific beam system design, should be determined before choosing a semi-rigid system. An authority should be sure that:

- They would be able to report and restore W-beam systems that were damaged during a collision quickly enough to ensure that adequate protection continuously;
- The necessary materials for routine and collision maintenance are readily obtainable and affordable;
- The maintenance personnel are adequately trained to ensure proper installation and maintenance; and
- They would confirm that the system is not considered for any of the restrictive conditions described previously.

### 2.13.9 Quality Control

Correct installation and collision maintenance are of the utmost importance to ensure that the barrier system functions properly and safely. When a specific type of W-beam system is chosen, it is important that the specific material as used by the original developers be used as the use of substitutes may lead to system failure and subsequent injuries.

The practice of straightening W-beam units that suffered minor damage in the collision and re-using them must be discouraged. Re-used beams have not been tested and certified as adequate. Such recycled beams may be used on pedestrian barriers or places where structural integrity is not critical.

## 2.14 RIGID SYSTEMS: CONCRETE

### 2.14.1 Introduction

The common occurrence of rigid RRS is in the form of concrete barriers of historically the New Jersey shape, which the F-shape is now superseding. These installations can be costly in situ or constructed with precast units. They are typically anchored to have zero working width. The concrete barriers have the highest containment level of H4b.

Rigid concrete barriers do not absorb any energy, and the impact of a vehicle causes higher forces on the occupants of the vehicle. It is, therefore, the barrier of the last option, as it is more of a hazard than the semi-rigid and flexible systems.

The wheels absorb the impact force at low angle impacts with a concrete barrier. The compression of the suspension system is used at higher impact angles. As the impact angle and speed increase, so does the vehicle's movement on the barrier. When a vehicle impacts a concrete barrier at an angle of less than 15 degrees, the vehicle tyre and the barrier make contact. The tyre deforms and absorbs energy. The front-wheel will climb up the barrier face at an increase in the impact speed. By lifting the vehicle, further kinetic energy is absorbed. The re-directional force perpendicular to the barrier is now applied to the suspension system. Depending on the speed, the wheel will continue the climbing movement to the upper section of the barrier. In this section, the wheels are turned parallel to the longitudinal axis of the barrier. This redirects the vehicle. If the impact speed is very high, the vehicle will continue the climbing movement on the face before returning to the roadway.

The SANRAL typical detail of the F-shape barrier is shown in the precast format in Figure 16. Note that the term F-shape refers to the letter allocated to this shape in a list of barriers tested against the New Jersey barrier. See the discussion under the heading Parapets.

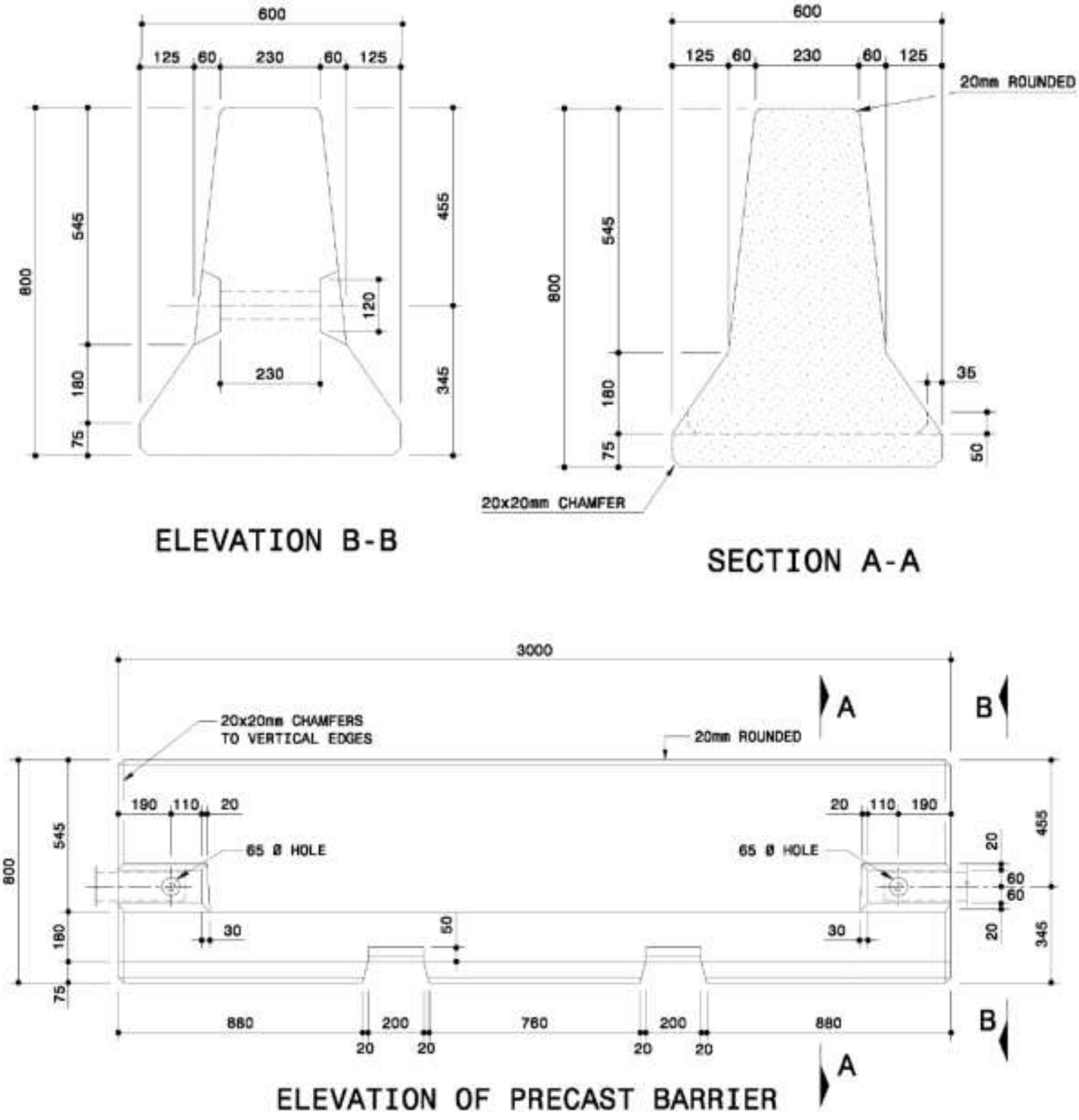



Figure 16: F-shape Precast Concrete Barriers (800 mm High Module)

### 2.14.2 Cast In Situ Concrete Barriers

Cast in situ concrete barriers, typically used on medians as separators for opposing traffic streams, are constructed with moulds and formwork of accurate dimensions and good quality control of steel reinforcement and concrete strength. They are fully anchored in the soil and often contained on the sides by the pavement layer works. These units do not have a deflection or working width. They are also used next to fixed objects such as gantry footings or bridge piers with no working width.

### 2.14.3 Precast Concrete Barriers

Precast concrete units are available to the SANRAL standard detail for one- and two-sided barriers and different heights. There is a number of proprietary products with different purposes, such as ease of deployment and movement on construction sites. If not anchored in position, the containment levels, deflection, and working width will depend on the connections and mass. Precast units can be used during construction and then installed in permanent positions. The concrete barrier nust conform to Containment Level H2 if there are no significant heavy truck movement, or H4b.

### 2.14.4 Connection of Precast Units

The connection between precast units must keep the barriers tied together and in position or on a curve during the deflection under any impact. All connections must conform to SANS requirements for steel connectors. It is important that individuel barriers must be connected in the way they were tested under EN 1317 of MASH.

### 2.14.5 Installation

The concrete barriers must be installed to the correct height and lateral position. The SANRAL typical drawings may be applicable, or the suppliers'installation manual.

### 2.14.6 Approach

As rigid concrete barriers are mostly used in confined spaces, the approach is typically flat and traversable. The design of ditches, channels or kerbs that could affect vehicle trajectory must consider the vehicle's stability hitting the barrier. On dual carriageways with narrow medians, drainage in curves is problematic as water runs to the centre of the road. The covers of such drainage channels should not be made of steel or other material valued as scrap. Composite grids must carry truck wheel loads to prevent the wheel from punching through and snagging in the channel.

### 2.14.7 Maintenance

The shoulder and space up to the barrier should be kept clean and free from any objects. Where precast units are used in temporary roadworks or barriers are not anchored, the working width behind the barriers must be kept clean and free from objects. The maintenance requirements are the lowest of all the barrier systems

### 2.14.8 Quality Control

Correct installation and provision of connections are important to ensure that the barrier system functions properly and safely.

## 2.15 PARAPETS

### 2.15.1 Introduction

The term parapet refers to the barriers on the edges of bridges but can also be located between the vehicle roadway and pedestrian path. In essence, parapets protect pedestrians and vehicles from falling off the bridge. In addition, they protect pedestrians from errant vehicles. They may be required to protect the area below. In special circumstances, they may be required to be solid, e.g., prevent splash, reduce noise, or screen railway electrification equipment. The current SANRAL typical details are based on the F-shape, and different heights are used for a road over road or water and road over rail bridges.

The design of parapets has been standardised for national roads by SANRAL to the profile of the so call F-shape. The 'F' does not imply that the shape refers to the letter F, but was numbered F in a series of simulations that systematically varied the parameters of barrier profiles labelled A through F. The result showed that the one labelled F performed better than the shape of the Jersey barrier. The design complies with the TMH 7 Code of Practice requirements for the Design of Bridges and Culvert in South Africa and is structurally strong enough for the highest containment level specified in the EN 1317. The forces and design assumptions for balustrades, as named in TMH 7, are shown in Appendix A. As such, the bridge code conforms to the level of containment H4b.

Application: to protect vehicles and pedestrians from falling off a bridge and the area below.

Purpose: the purpose of parapet can be seen in the following definitions:

- Vehicle parapet: a parapet designed to contain vehicles on a section of a structure from which pedestrians, animals and cyclists are excluded. Parapets are intended to protect pedestrians and vehicles from falling off the structure;
- Pedestrian parapet: a parapet designed to safeguard pedestrians but not intended to contain vehicles; and
- Vehicle/Pedestrian parapet: a parapet designed to contain vehicles and to safeguard pedestrians.

## 2.15.2 Example of Parapets

The following Figures 17 and 18 were extracted from the SANRAL typical drawings.

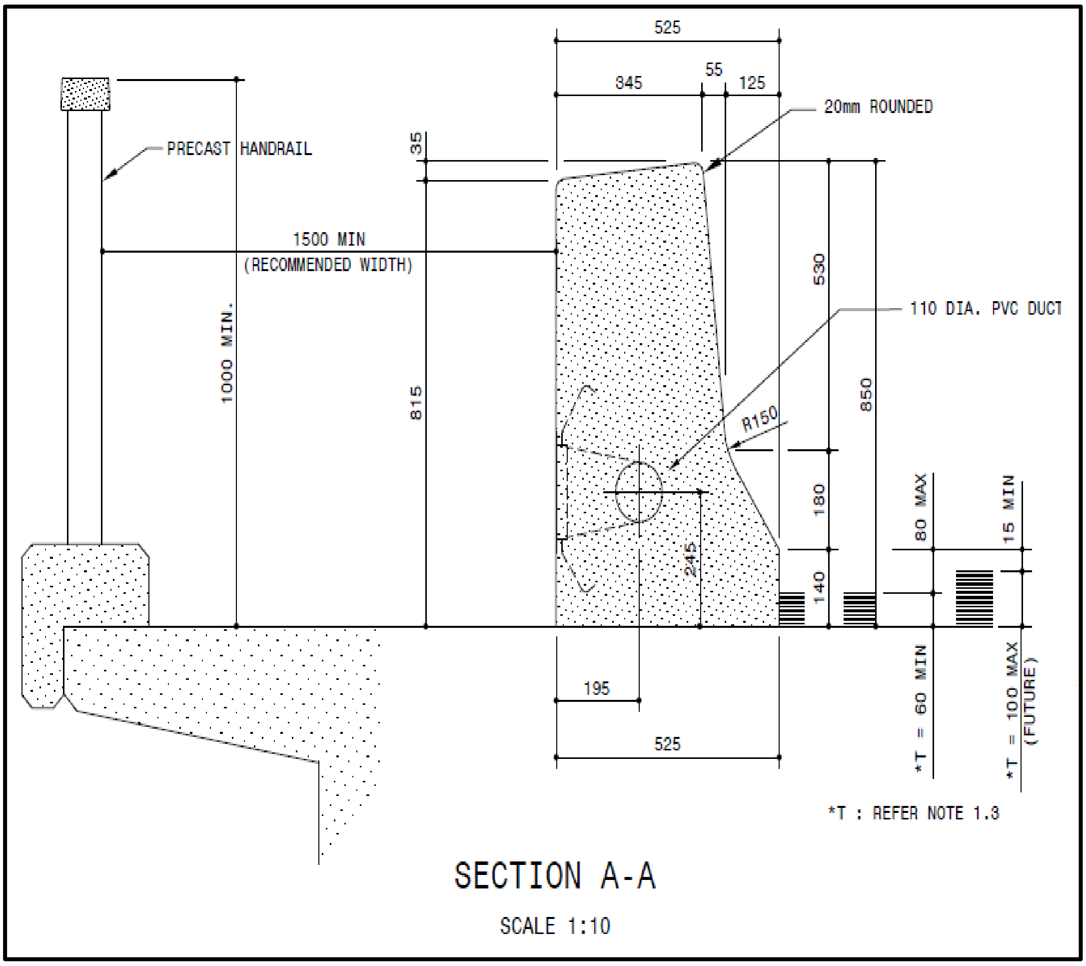



Figure 17: F-shaped Parapet for Use on Bridges with Separate Pedestrian Path

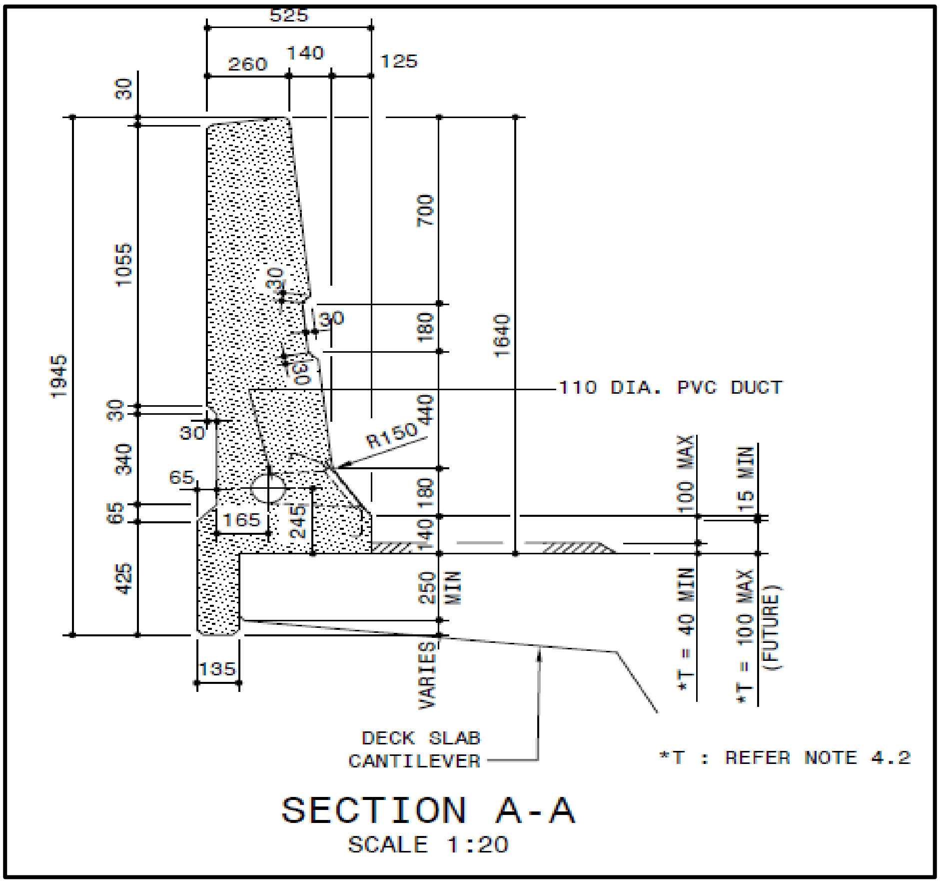



Figure 18: F-shaped Parapet for Use on Railway Bridges

### 2.15.3 Installation Requirements

Bridge parapets are mostly cast in situ as part of the bridge structure. They can be precast and cemented onto the bridge deck with sufficient reinforcing steel to prevent sheer or rotation when hit.

### 2.15.4 Maintenance

Bridge parapets are maintained as part of the bridge. Under South African treasury regulations, most road authorities have set asset management regimes as required. Bridges are regarded as a high priority for maintenance, as the consequences of a bridge failure would be catastrophic or very costly.

## 2.16 TERMINALS

The use of straight ramped down terminals for new projects is not permitted. The existing straight ramped terminal should be phased out progressively on all high-speed (80+ km/h) or high-volume (6000+ vehicles/day) roads. The terminal must be flared as per SANRAL typical drawings to reduce the risk of hitting the low part of barrier.

Several different end-treatments are available for the various types of barriers to shield roadside hazards in the shoulders, gore areas, and the medians of roads. A proper end terminal has two functions:

- For any non-rigid barrier system, the end terminal must act as an anchor to allow the full tensile strength of the system to be developed during downstream angled impacts on the barrier; and
- Regardless of the type of barrier, the end terminal must be crashworthy, i.e. it must keep the vehicle stable (eliminate overturning, spearing or vaulting), and it must keep the vehicle occupants away from rigid points creating high deceleration resulting in serious injuries or death during impact.

### 2.16.1 Gating End-Terminal Systems

Gating systems have not been used in South Africa in the past. The use of gating systems will not be advised in this manual.

These are systems designed to break away when impacted at an angle, allowing the vehicle to pass through the barrier line onto a cleared and traversable area behind the guardrail barrier. Currently, this cleared runout area has been set at 22.5 m long x 6 m wide with a slope of a maximum of 1:10 for 1 m on either side of the barrier.

The most significant disadvantage of a gating end treatment is that the reinstatement after impact is crucial for the proper functioning of the terminal.

### 2.16.2 Non-Gating End-Terminal Systems

A non-gating terminal is designed to safely decelerate an errant vehicle that impacts on an angle at the nose. It will redirect a vehicle impacting at any other point along the barrier **without** allowing it to pass behind the barrier.

The road goes from cut to fill, and an RRS is justified on the fill, a satisfactory terminal can be achieved by anchoring the W-section guardrail in the back slope where an adequate roadside area is available. Proper flare rates and full barrier height need to be retained throughout.

Flared end-treatments can also be designed as non-gating terminals so that their geometry flows with, rather than opposes, the direction of traffic flow.

### 2.16.3 Trailing End Terminals (e.g. End-Wings)

In the past, the trailing ends of guardrail installations were often formed by the simple fixing of Type 1 end-sections (end-wings). However, errant vehicles could impact a guardrail on the wrong side of the road. Non-protected blunt end-sections to guardrails will not be allowed on new projects road authorities must budget and programme to replace these with more appropriate terminals.

### 2.16.4 Blunt Terminals

In the past, the trailing ends of guardrail installations were often formed by the simple fixing of Type 1 end-sections (end-wings). Errant vehicles would often be found to impact a guardrail on the wrong side of the road. The use of spoon or winged ends as terminals is not permitted on the leading ends of guardrails or trailing ends where there is a possibility of vehicles hitting those ends. The use of bullnose terminals is not permitted. Non-protected blunt end-sections to guardrails will not be allowed on new projects

Legacy installations of hazardous terminals must be subjected to a network-wide risk assessment, and remedial procedures must be developed based on risk, with a horizon to eliminate all non-conforming terminals.

### 2.16.5 Construction Concerns

The construction procedure for terminals varies extensively depending on the type of terminal selected. The following aspects are relatively familiar to most systems and need to be appropriately assessed:

- Position of the terminal;
- Roadside grading;
- Foundation conditions;
- Terminal layout (horizontal and vertical); and
- Meticulous attention to design details.

### 2.16.6 Flare

Safety barriers should be installed per the manufacturer's requirements. Where these allow and wherever practicable, the ends of barriers should be flared. There are three functions of the flare:

- To locate the barrier and its terminal as far from the carriageway as is feasible;
- To minimise a driver's reaction to the introduction of an object near the carriageway; and

- To reduce the length of need.

However, flaring may not be appropriate at full height terminals.

It has been shown that an object (or barrier) close to the carriageway may cause a driver to shift laterally, slow down, or both. The flare reduces this reaction by gradually introducing the barrier so that the driver does not perceive the barrier as a hazard. However, a flare increases the angle at which a vehicle will impact the barrier. A compromise between flare and impact angle is needed. Flare rates steeper than 1:20 should, therefore, not be used.

The following general principles apply:

- Vehicles should not be able to pass easily behind the approach flare; and
- Anchorages and concrete ramps on central reserves should not be located, so they protrude into the deflection space of the opposite fence.

Flare rates of up to 1:20 may also be used:

- If to do so does not conflict with the manufacturer's requirements; and
- If it is necessary to change the setback of a barrier (e.g. at the approaches to bridge piers in the central reserve).

The SANRAL flared terminal for semi-rigid RRS is shown in the typical detail drawings TD-R-GR_1100-V1 and TD-R-GR-1101-V1 Guardrails Detail of terminal sections Sheets 1 of 2 and 2 of 2. An extract is shown in Figure 19.

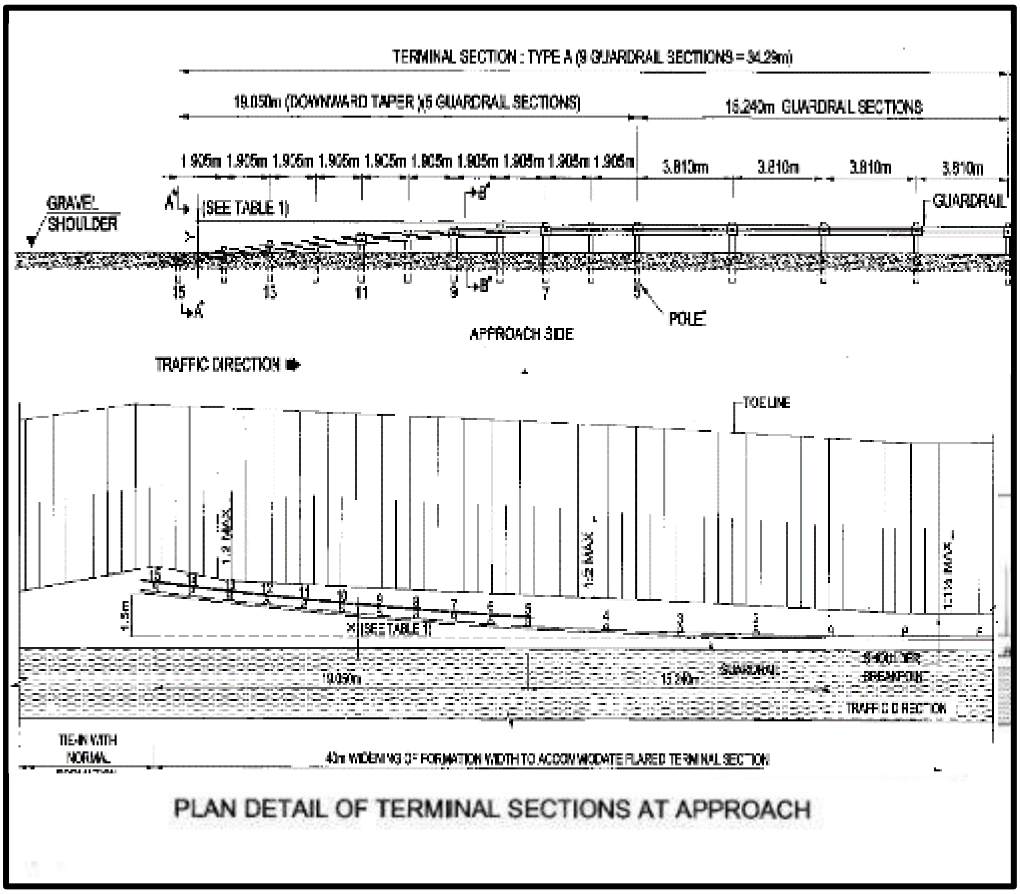



Figure 19: SANRAL Typical Terminal Sections

The Buried in Backslope terminal is advised where the road alignment goes from cut to fill (Figure 20).

Figure 20: Buried in Backslope Barrier Terminal

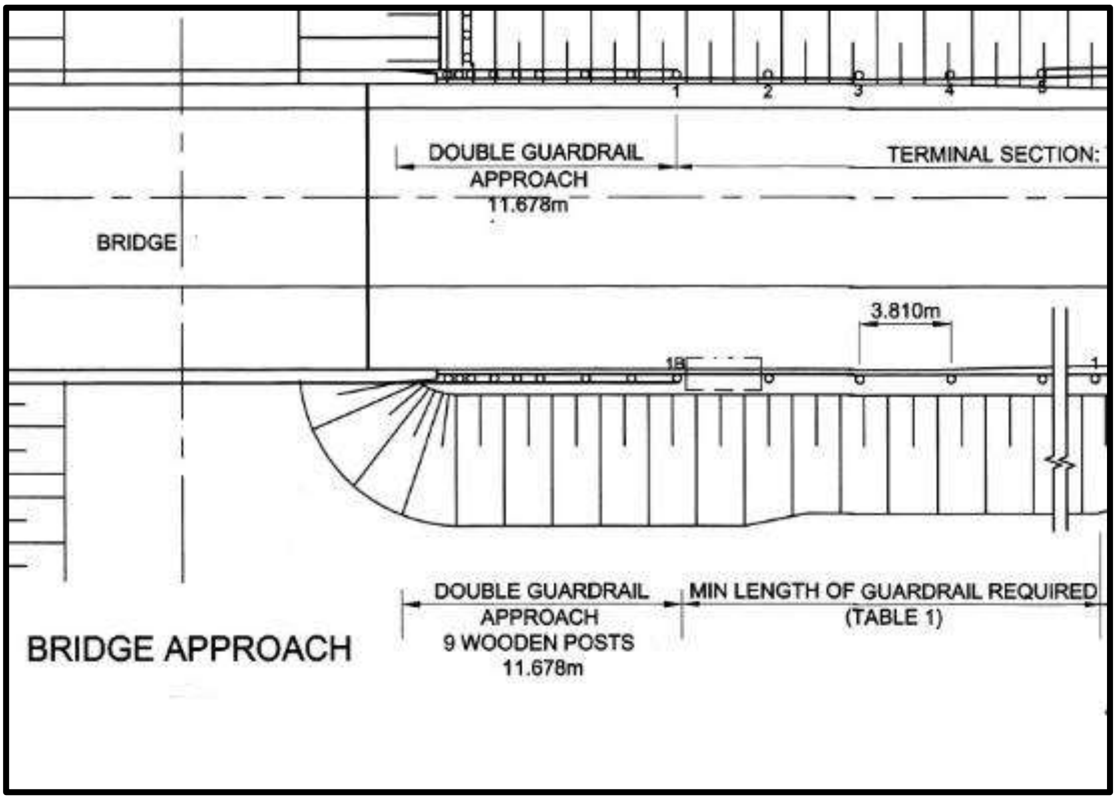
The use of crash cushions as RRS terminals is expensive. If used, the design must follow the requirements of EN 1317 Part 3.

## 2.17 TRANSITIONS

Transitions are the sections that link RRS of different containment, working width and stiffness (semi-rigid to rigid). Flexible barriers should not be combined with other systems. Changing between two safety barriers having the same type, cross-section and material and differing no more than one class of working width is not considered a transition.

The critical case is linking a semi-rigid RRS to a rigid RRS or bridge parapet, where the lesser stiffness increases and the higher working width reduces. This can give rise to pocketing, where the first part of the system deflects, and the vehicle hits the rigid section head-on. The transitions must be long enough and of increasing stiffness to guide the vehicle past the start of the rigid section.

The typical transitions are from a semi-rigid W-steel section to a rigid parapet. The SANRAL typical detail on Drawing TD-R-GR-1200-V2 Guardrails placing detail at bridge approaches and high fill (Dual carriageway) of the transition is over three double-sided lengths of standard 3.81 m rails with the use of nine posts with decreasing spacing as shown in Figure 21.



The connection to the parapet is illustrated in Figure 22.

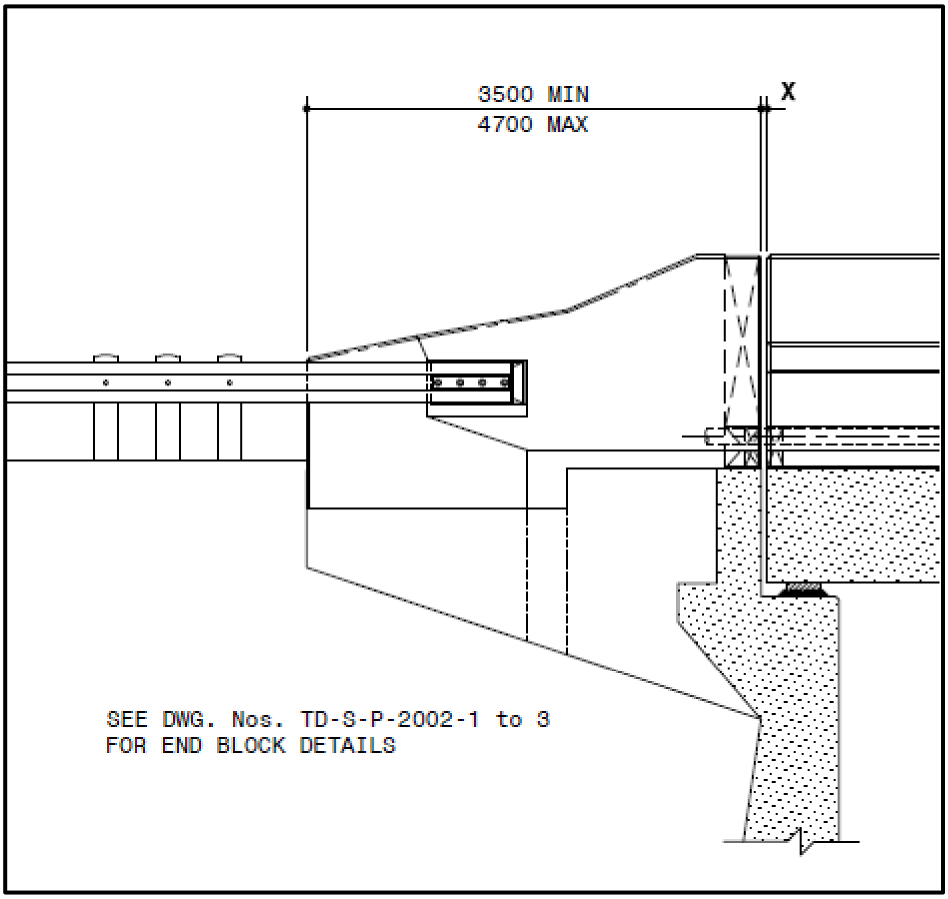


Figure 22: Transition Between Bridge Parapet and W-Beam Barrier

# 3 CRASH CUSHIONS (IMPACT ATTENUATING DEVICES)

## 3.1 INTRODUCTION

Crash cushions or impact attenuators prevent vehicles from impacting a barrier or fixed objects by the controlled deceleration of the vehicle or by directing the vehicle away from the hazard. They are ideally suited for terminating rigid barriers or for use where longitudinal barriers would not effectively shield objects that cannot be removed or relocated.

Typical objects and areas that can benefit from the use of impact attenuators include:

- A freeway exit ramp gore area in an elevated or depressed structure where a bridge rail end or a pier requires shielding;
- The ends of roadside or median barriers;
- Rigid objects like cantilever sign gantries within the clear zone; and
- The ends of certain 'dead-end.'

Crash cushions can be re-directive or non-directive. Crash cushions are routinely provided at toll booth islands and can be provided at bridge piers, billboard columns, the start of concrete barrier RRS and major fixed objects in the clear zones. The tests can be head-on or from different angles and offsets.

## 3.2 RISK

The risk of run-off-road events hitting a fixed object was discussed previously. If not using a barrier, the shielding of a fixed object should be with a crash cushion. This has a lower risk due to the smaller exposure area than an extended barrier, which can be a hazard. A proven risk for hitting a fixed obkect vis at toll plazas. The toll plaza is designed for vehicles driving through and errand vehicles may encroach on the front blunt end of the booth.

## 3.3 DESIGN

Crash cushions on South African roads will be limited to EN 1317 Part 3 tested proprietary systems. No untested system such as sand or water-filled drums will be allowed.

The order of priority for design is still to:

- Remove the hazard;
- Redesign the hazard so that it can be safely traversed or contacted;
- Relocate the hazard to reduce the probability of it being traversed or contacted;
- Reduce the severity of the hazard;

- Shield the hazard; and
- Delineate and increase the driver's awareness of the hazard when other mitigation measures cannot be made to work.

Where a hazard cannot be mitigated, a crash cushion can be considered. Toll road booths are a particular object to be shielded by crash cushions. See Figure 23.

Figure 23: Crash Cushion at Toll Booth

Source: Armco Superlite Brochure

Typical situations where the need for crash cushion applications exists is shown below in Figure 24.

Figure 24: Illustrations of Need for Crash Cushions

Shielding the hazard utilising a crash cushion must be based on the need for a level of protection/containment, affected by impact severity (speed, mass of typical vehicle), vehicle trajectory and crash cushion deflection (working space). The projection and distribution of test vehicle and crash cushion debris post-crash is also part of the acceptance criteria.

Crash cushion performance is tested to determine the impact severity levels and to ensure that the vehicle occupants suffer no severe injuries due to the movement of the head. The Acceleration Severity Index (ASV) and Theoretical Head Impact Velocity must be within set values. See Table 11.

TABLE 11: VEHICLE IMPACT SEVERITY VALUES

| Impact severity levels | Index values | | |
|---|---|---|---|
| A | ASI ≤ 1,0 | and | THIV ≤ 44 km/h in tests 1,2 and 3<br>THIV ≤ 33 km/h in tests 4 and 5 |
| B | 1,0 < ASI ≤ 1,4 | | THIV ≤ 44 km/h in tests 1,2 and 3<br>THIV ≤ 33 km/h in tests 4 and 5 |
| NOTE The limit value for THIV is higher in tests 1, 2 and 3 because experience has shown that higher values can be tolerated in frontal impacts (also because of better passive safety in this direction). Such a difference in tolerance between frontal and lateral impacts is already considered in the ASI parameter, which therefore does not need to be changed. | | | |

## 3.4 CRASH CUSHION BEHAVIOUR

Elements of the crash cushion shall not penetrate the passenger compartment of the vehicle. There shall be no deformations of, or intrusions into the passenger compartment that could cause serious injuries to the occupants.

All totally detached parts of the crash cushion with a mass greater then 2.0 kg shall be included in the determination of the displacement classification.

Foundations, ground anchorages and fixings shall perform according to the design of the crash cushion. The deformed crash cushion shall not encroach into the front surface of the obstacle.

Table 12 shows the test numbers for the different speeds and approaches.

TABLE 12: VEHICLE IMPACT TEST DESCRIPTIONS FOR CRASH CUSHIONS (FROM EN 1317 PART 3)

| Test[a] | Approach | Total vehicle mass kg | Velocity km/h | Figure 3 Test no. |
|---|---|---|---|---|
| TC 1.1.50<br>TC 1.1.80<br>TC 1.1.100 | Frontal centre | 900<br>900<br>900 | 50<br>80<br>100 | 1 |
| TC 1.2.80<br>TC 1.2.100 | | 1 300 | 80<br>100 | 1 |
| TC 1.3.110 | | 1 500 | 110 | 1 |
| TC 2.1.80<br>TC 2.1.100 | Frontal,<br>¼ vehicle offset | 900[b] | 80<br>100 | 2 |
| TC 3.2.80<br>TC 3.2.100<br>TC 3.3.110 | Head (centre), at 15° | 1 300<br>1 300<br>1 500 | 80<br>100<br>110 | 3 |
| TC 4.2.50<br>TC 4.2.80<br>TC 4.2.100<br>TC 4.3.110 | Side impact at 15° | 1 300<br>1 300<br>1 300<br>1 500 | 50<br>80<br>100<br>110 | 4 |
| TC 5.2.80<br>TC 5.2.100<br>TC 5.3.110 | Side impact at 165° | 1 300<br>1 300<br>1 500 | 80<br>100<br>110 | 5 |

[a] Test notation is as follows:

| TC | 1 | 2 | 80 |
|---|---|---|---|
| Test of crash cushion | Approach | Test vehicle mass | Impact speed |

[b] For this test condition, the ATD shall be located at the more distant location from the centre line of crash cushion.

The trajectory of the test vehicle is shown in Figure 25. The designer must ensure that the design fits within narrow deviations into the standard test parameters; otherwise, the outcomes cannot be reliably predicted.

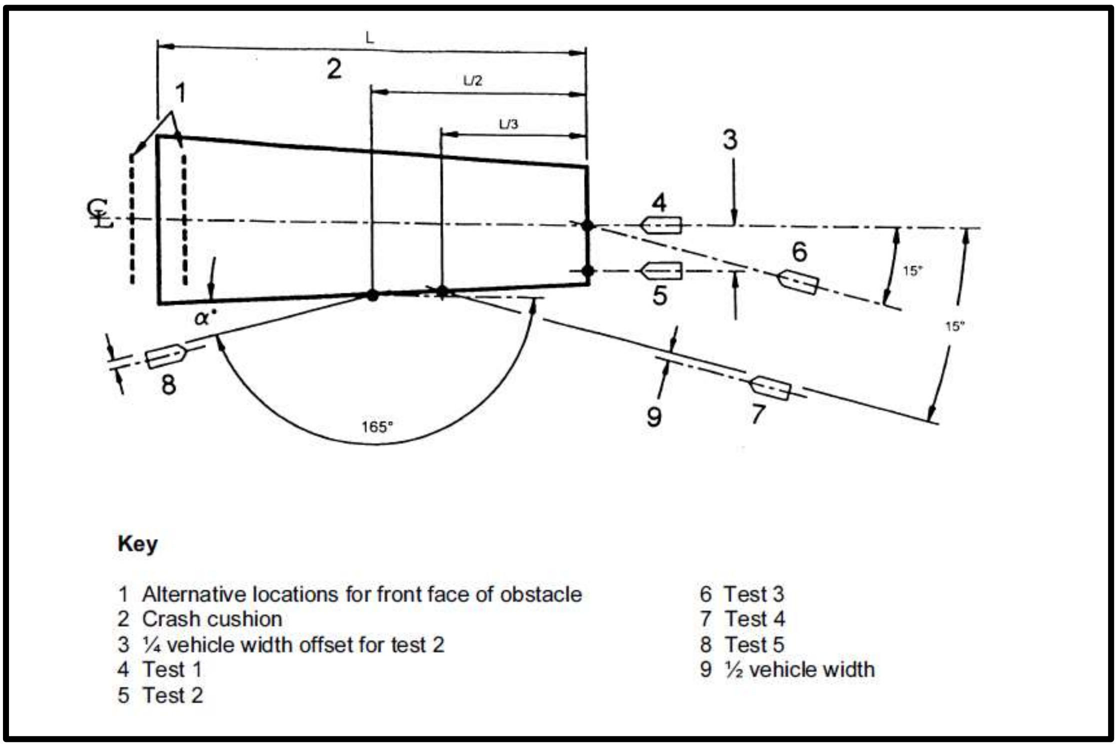


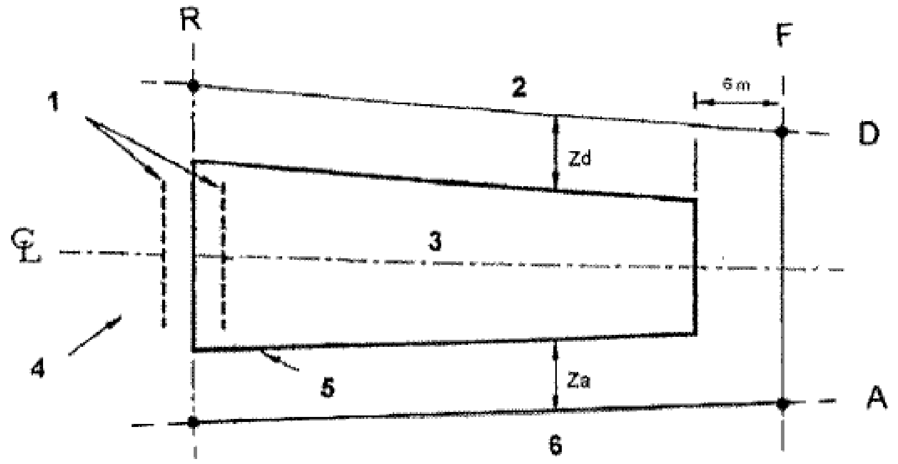

Figure 25: Crash Cushion Test Configurations

## 3.5 TEST VEHICLE BEHAVIOUR

The vehicle shall not roll over (including rollover of the vehicle onto its side) during or after impact.

The post-impact trajectory of the test vehicle shall be evaluated by means of the exit box. The exit box is limited by:

- The rebound line F, perpendicular to the crash centre line, 6 m upstream of the crash cushion head;
- The two side lines A and D, parallel to the two sides of the trapezoidal envelope as defined are specified distances (Za on the approach side and Zd on the departure side) on the approach side and on the departure line;
- The line R perpendicular to the centre line at the end of the crash cushion;
- A broken line that represents the front face of the obstacle to be protected; this line shall be specified in the design of the crash cushion and reported in the test report =- it may be inside of outside the crash cushion envelope.




**Key**
1 Alternative locations for front face of obstacle
2 Departure side
3 Crash cushion centre line
4 Exit area
5 Trapezoidal envelope enclosing crash cushion
6 Approach side

NOTE For R, F, D, A, Za and Zd, see 6.3.

Figure 26: Ground Reference Plan

## 3.6 PERFORMANCE SPECIFICATION

The primary specification for crash cushions is the speed at which a vehicle approaches the hazard. Therefore, the performance level is specified as a speed related to the acceptance test. Secondary performance specifications are the deflection of the crash cushion under impact and the spreading of debris from the components. The tests consider a range of impact angles, and the vehicle's exit from a side impact as indicated on the ground reference plan can be checked.

TABLE 13: PERFORMANCE LEVELS FOR CRASH CUSHIONS

| Level | Acceptance test | | | | | |
|---|---|---|---|---|---|---|
| 50 | TC 1.1.50 | - | - | - | TC 4.2.50[a] | - |
| 80/1 | - | TC 1.2.80 | TC 2.1.80 | - | TC 4.2.80[a] | - |
| 80 | TC 1.1.80 | TC 1.2.80 | TC 2.1.80 | TC 3.2.80 | TC 4.2.80[a] | TC 5.2.80[a] |
| 100 | TC 1.1.100 | TC 1.2.100 | TC 2.1.100 | TC 3.2.100 | TC 4.2.100[a] | TC 5.2.100[a] |
| 110 | TC 1.1.100 | TC 1.3.110 | TC 2.1.100 | TC 3.3.110 | TC 4.3.110[a] | TC 5.3.110[a] |
| [a] Relevant for the redirective crash cushions only. | | | | | | |

Examples of crash cushions are shown in Figure 27.

Figure 27: Crash Cushions

Source: Quadguard TM

# 4 VEHICLE ARRESTOR BEDS

## 4.1 INTRODUCTION

The number of vehicle arrestor beds (VAB) in South Africa is fewer than 20. Arrestor beds are expensive to build and constantly maintain. The justification for a VAB will be very site-specific, based on crash history from which a risk assessment and economic analysis can be done. The primary considerations are long steep gradients such as in mountain passes where there is a risk of drivers overusing the brakes instead of crawling down in lowest gear, a condition on the pass or at its end that requires stopping, high truck volumes and no viable alternatives.

## 4.2 SANRAL TYPICAL DESIGN

Figures 28 and 29, from the SANRAL GDG, show the plan and vertical alignment layout. This design evolved from several successful VAB installations.

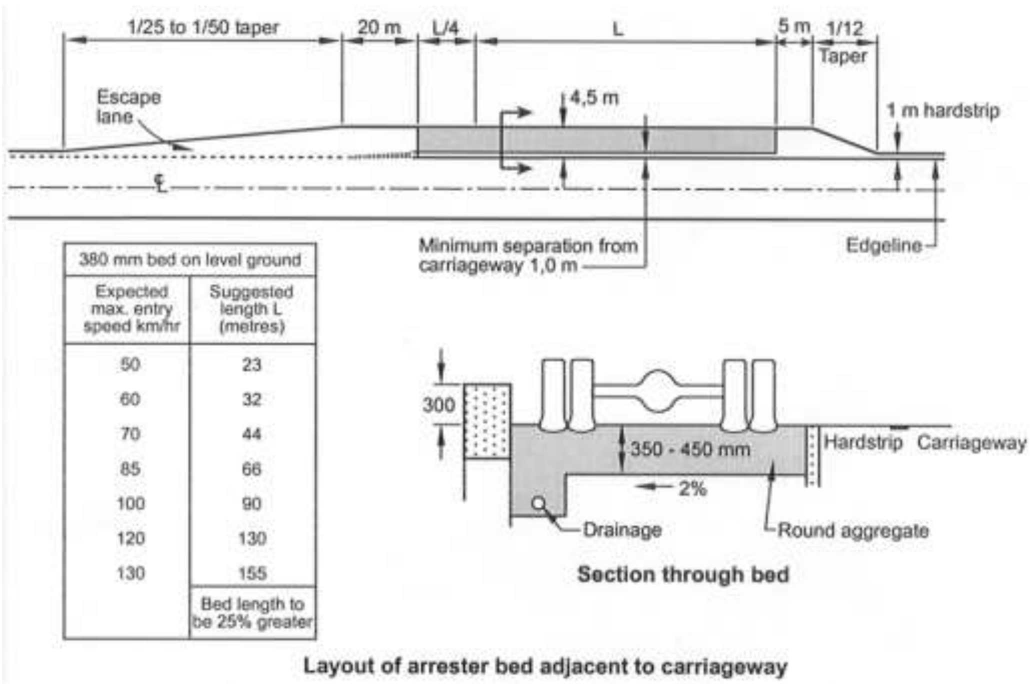



Figure 28: Layout of Arrestor Bed Adjacent to the Carriageway

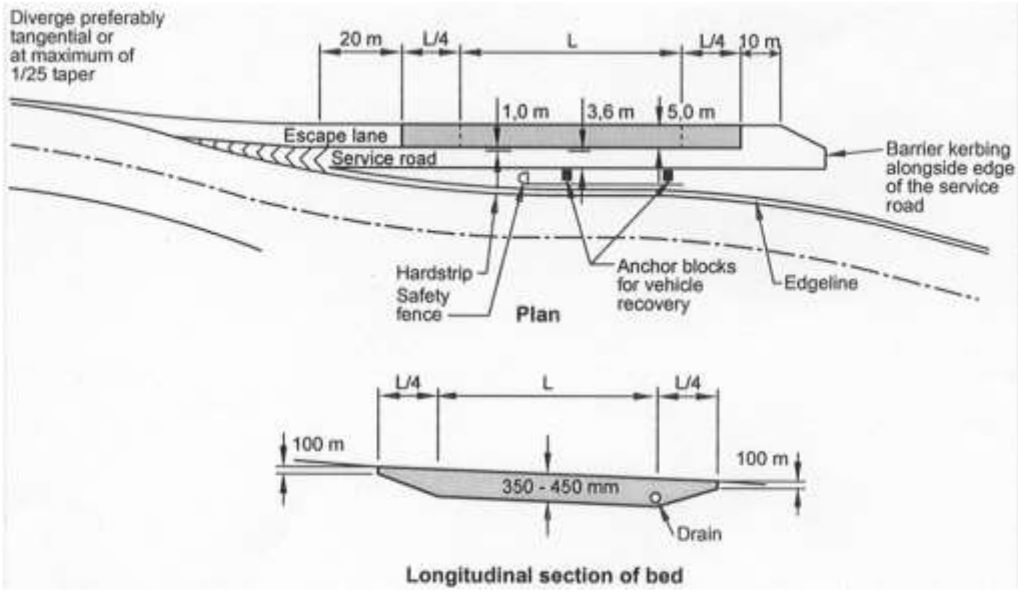



Figure 29: Layout of Arrestor Bed Remote from the Carriageway

The SANRAL designs are adequate for the largest heavy vehicle used in South Africa, with a GVM of 56 t. This is typically a laden interlink combination with a truck tractor and two trailers at 22 m in length.

As arrestor beds are located at known high-risk areas, a brake check area or a compulsory truck stop should be provided before the downgrade in an area set aside before the steep descent as distinct from a brake rest area which is an area set aside for commercial vehicles part way down or at the bottom of the descent. Such compulsory stops can be implemented where arrestor beds are not yet warranted.

The selection of appropriate aggregate for the VAB is critical: the most effective aggregate is a single size < 13.2 mm rounded stone. Flaky aggregate compacts over time and is challenging to fluff (plough through to loosen the material that can become contaminated with dirt and dust, resulting in compaction and cementation).

# 5 ROAD SIGN GANTRIES AND ADVERTISEMENT SUPPORTS

## 5.1 INTRODUCTION

Road sign gantries and billboard advertisement supports are substantive structures spanning freeway carriageways or supporting sign faces of 6 m x 4 m. These supports are connected to concrete bases that often rise above the ground level and pose significant hazardous fixed objects. These bases are located outside the roadways and in the medians of dual carriageway roads. Narrow shoulders and medians often limit the working width available for an RRS. See Figure 30.

Figure 30: Illustration of Gantry Base in Median

## 5.2 SPECIFICATION

The protection of gantry and sign bases must conform to the design principles of RRS and the EN 1317 standard tests. The design vehicle can be light with a normal containment level (N1 in urban and N2 in rural conditions). Where a sign gantry is located in a high-risk or hazardous location on a route carrying high volumes of heavy vehicles, the containment level can be raised to H2 following a risk assessment.

# 6 TEMPORARY BARRIERS

## 6.1 INTRODUCTION

The design of RRS for temporary works is a complex matter due to the wide range of road conditions, the constantly varying work zones and traffic conditions.

South African Road Traffic Signs Manual Chapter 13 – Section 13.5.4:

- Barriers must be sufficiently fixed to give physical protection to traffic and workers alike. Typical barriers are W-section steel or portable shaped concrete (New Jersey) section mounted following prevailing SABS requirements. The alignment of barriers shall be defined for night-time visibility by guardrail delineators or similar devices. Special effort should be taken to make the face of concrete section barriers visible, particularly at night and under conditions of bad visibility; and
- When portable concrete barriers are used, particular attention should be paid to the end treatment of the barrier. On low-speed approaches, a minimum of three sections should be tapered away from the line of traffic flow, and a loose sandbag or open-graded stone heap should be placed at the end facing oncoming traffic (note: the specification for open-graded stone should be as for use in arrestor beds). This treatment should always be used on high-speed approaches unless a full standard taper or curve of portable barriers is used to offset the end from the path of approaching traffic (see Figure 13.28).

The design, operation and management of traffic accommodation are the contractor's responsibility, but there is a view that the consulting engineer must plan for traffic accommodations in designing for constructability.

SANRAL, in consultation with the contractors and labour unions, took a policy decision with the Gauteng Freeway Improvement Scheme to separate workers through concrete barriers wherever possible. This can be justified due to the high traffic volumes, speeds, working in the median and number of lanes where traffic could drive adjacent to the work zones. This would not be feasible on a rural road contract with low traffic volumes that can effectively be slowed in single lanes. There is no one size fits all simple solution.

The principles of RRS design on a construction site are the same as for permanent installations, and all other options for delineation, control, regulation and guidance must be completed before looking at temporary barriers. The design of temporary barriers will look at levels of containment, length of need, terminals and transitions, and the same EN 1317 standards must apply. The contractor can propose alternative systems, but whatever system is proposed, it must be certified as having passed the EN 1317 or MASH tests. The advantage of a construction site is that speed can be lower with drivers having expectations of delays and that the design vehicle, in most instances, can be taken as a light vehicle. Professional truck drivers are more alert on construction sites.

The design of the actual barrier within the length of need is probably the simplest step, but terminals are problematic. Tested proprietary systems of terminals and crash cushions require proper rails to the ground to guide the system to perform, which may not be possible on the construction site or is very expensive.

The South African Road Traffic Sign Manual Volume 2 Chapter 13 (Signage for Roadworks) provides some guidance in Figure 13.28 on the flaring of the approach terminal. It indicates that the first concrete barrier (a steel or W-beam barrier) must be 6 m away from the travelled lane. This is basically on the edge of the clear zone, where no terminal is required. The end must be properly signed. In practice, contractors tend lto refer to the second part of the figure where the end is provided with the so-called Sandbag End Treatment. This is then often used as a terminal but is placed as close as 1 m from the edge of the lane. The Sandbag End Treatment is a hazard, as the material is hard and heavy; it also has been observed that sandbags have been placed in a gabion basket. Such practices need to stop. The flare must be offset sufficiently, so the end is not a direct hit risk See Figures 31 and 32.

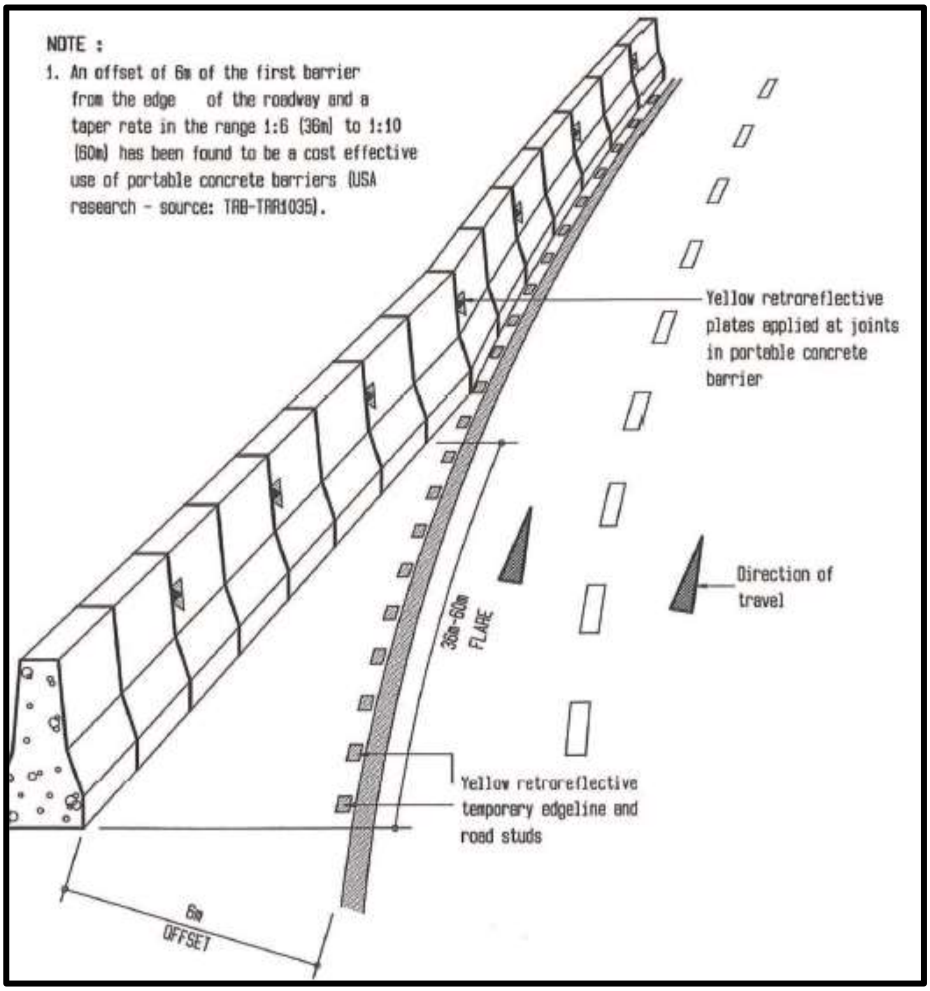



Figure 31: Barrier Offset for Roadworks

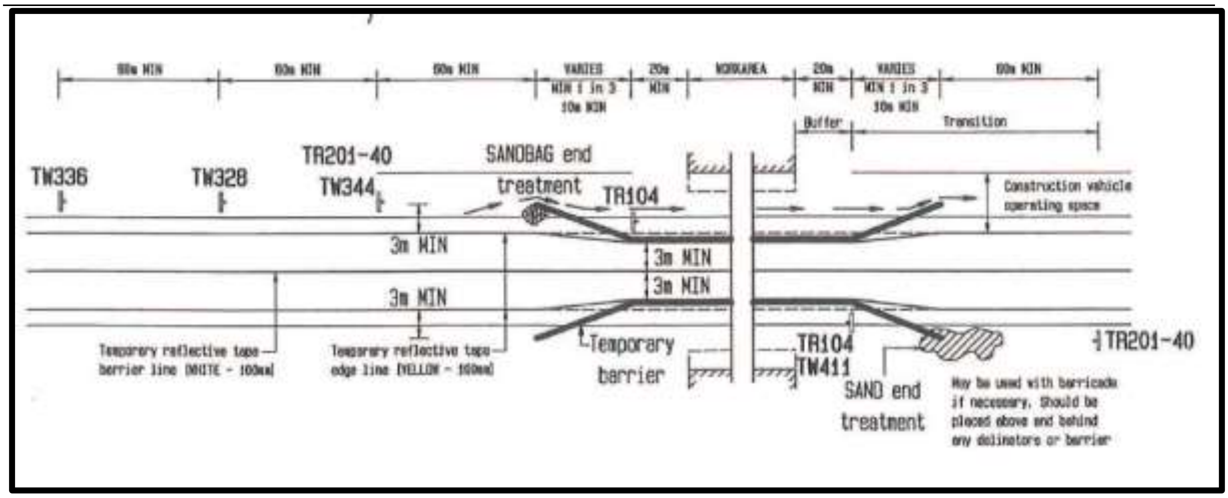



Figure 32: Layout of Barriers at Work Zone

The RRS used must be used under the same conditions as they were tested. That includes minimum length, tied together and aligned in a smooth line. Figure 33 shows units that were not toed together and did not act as a system.

Figure 33: Incorrect Use of Barriers in the Work Zone

The use of yellow plastic units is not considered a barrier. They are at best, an obvious line of delineators. They will not protect workers from vehicle encroachments. See Figure 34.

Figure 34: Yellow Plastic Units Used as Delineators

## 6.2 SPECIFICATION

The design of RRS for roadworks and traffic accommodation must conform to the same design parameters as permanent installations, with due consideration for worker safety. The minimum containment level is N1 in urban areas and H2 in rural areas to account for heavy vehicles at low speed.

# 7 PEDESTRIAN AND CYCLIST RESTRAINTS

## 7.1 INTRODUCTION

NMT is a specific focus of transport planning and design, and policies have been developed at the national, provincial and local government levels to ensure better accommodation of walking and cycling. The safety of vulnerable road users is acknowledged in strategies such as the safe system, with pillars Safer Road Users, Safer Roads and Safer Speeds.

The separation of vulnerable road users from motorised traffic is ideal, and often, the opportunity is often not only to barricade the vehicles but also to prevent pedestrians and cyclists from encroaching onto the road and road shoulders.

## 7.2 OPTIONS

The provision of structurally sound pedestrian restraint systems is necessary on bridges to fall from high heights, land in water, or other roads. This design issue was discussed under bridge parapets. The pedestrian and cyclist restraints options can therefore be focused on softer or lighter barriers.

## 7.3 RAILS

Pedestrian rails can be used to direct NMT traffic to specific crossing points where it can be safer, such as traffic light-controlled crossings, yield controlled crossings or locations where pedestrian refuge islands can be constructed in the road to split the crossing into two stages.

There are currently no standards for pedestrian rails, but from the product brochures, particularly from the United Kingdom, there appear to be some common elements in the design of these rails. They typically comprise of panels 0.9 m high and 2 m long, a frame of 50 mm x 30 mm rectangular tubing and 12 mm round bar vertical rods (pales) at 100 mm spacing, erected so that the top is 1.0 m from the ground. There are variations where a third rail is inserted about 200 mm below the top rail and the vertical rods stopping short providing a see-through slot. There are also various decorative rails for use in historic areas. The frame seems to provide adequate stability.

The use of pedestrian rails to direct movement is rare in South Africa, partially because such steel items are stolen.

It is proposed that a standard design be adopted with the see-through slot for use in urban areas. See Figure 35.

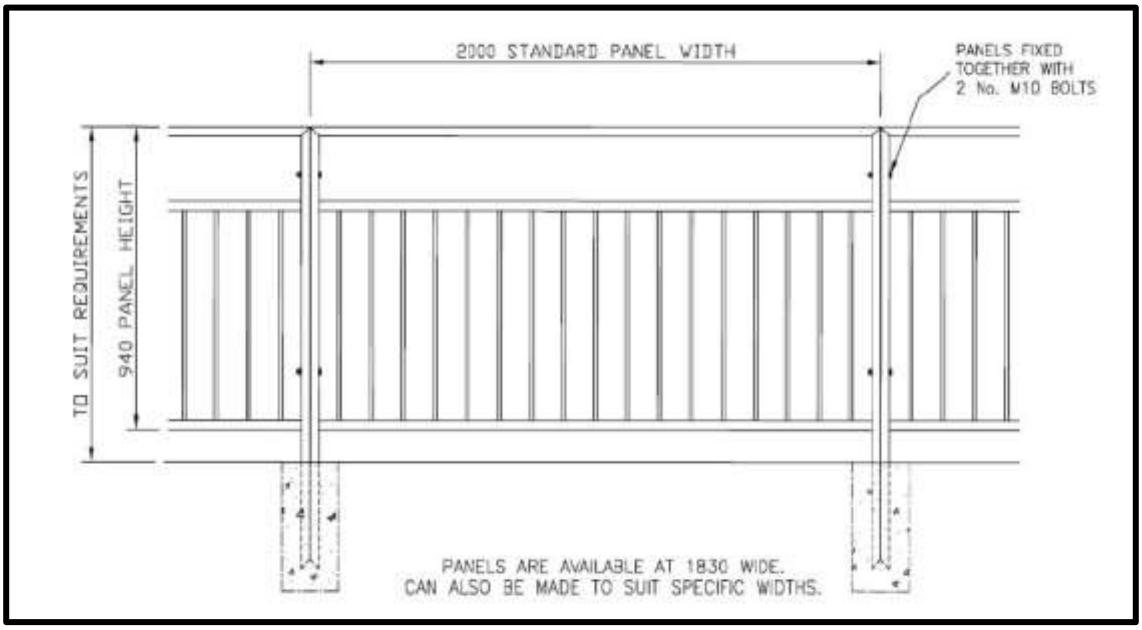



Figure 35: Pedestrian Railing

## 7.4 BOLLARDS

Bollards can be used to separate pedestrians, cyclists and vehicular traffic. Bollards, made from concrete, steel pipe or wooden posts, are used widely to prevent vehicles from parking on sidewalks. There is no need for a standard specification on bollards, as these are an urban design issue. The most cost-effective solution for rural areas are wooden posts similar to guardrail posts, treated for durability.

## 7.5 FENCING

SANRAL has used proprietary fencing products, such as concrete and steel palisades and welded mesh to control access to freeways and over freeway medians. These measures have had limited success, as there only need to be a small number of gaps to render the effect useless. In recent years so-called ‘anti-climb’ proprietary fencing has gained widespread use.

# 8 RAILWAY LEVEL CROSSINGS

## 8.1 INTRODUCTION

The Road Safety Regulator (RSR) reviewed the design of railway level crossings and led to the development of the SANS 3000-2-2-1 Technical requirements for engineering and operational standards: Track, civil and electrical infrastructure – Level Crossings, 2012.

The RSR and Transnet implemented a pilot project aimed at the ultimate safe railway level crossing design at Boschhoek near Rustenburg on the dual-line to Thabazimbi. The design featured rotating barriers that rise from the road and can stop trucks. The installation is intended for rural areas with electricity from the main railway supply, which makes them independent of load shedding or other supply failures. Maintenance vandalism are a major drawback, especially in recent years. See Figure 36.

Figure 36: Boschhoek Railway Level Crossing with Barriers

## 8.2 RECOMMENDATION

It is not recommended that such sophisticated systems be deployed. The standards for control of level crossings must otherwise be following SANS 3000.

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# 9 ANNEXURE A: RISK ASSESSMENT PROCEDURE

**NOTES**

- **THIS ANNEXURE MUST BE READ IN CONJUNCTION WITH THE NETSAFE 3 DOCUMENT;**
- **THE RAPSA APPLICATION IS AVAILABLE AS AN EXCELL SPREADSHEET AND FORMS PART OF THIS VOLUME.**

## 9.1 INTRODUCTION

The main aim of road restraint systems (RRS) is to contain and redirect errant vehicles to avoid injury to occupants and reduce the damage to vehicles and infrastructure. The South African Road Restraint Manual (SARRM) is part of the South African Road Safety Manual series of documents that have been developed to assess or audit road safety conditions, identify areas that require improvement and provide guidance to improve road safety on the South African road network, including the installation of RRS.

The SARRM is a technical guideline to assist road authorities and practitioners responsible for the planning and design of roads and is not intended to address the duty or responsibility of road authorities.

RRS forms an integral part of the road planning and design process and requires detailed knowledge of civil, transportation and traffic engineering and road safety principles.

Guardrails compromise the conflicting demands of construction cost and safety but are themselves also a hazard. **To be warranted, the guardrail should be a lesser hazard than whatever hazard they intended to prevent while the Benefits/Cost >1.**

After several investigations, it was decided to base the South African risk assessment on the NetSafe Highway Safety Model, 2019. Netsafe was developed as a safety model and implemented by SANRAL in the South African Road Design System.

The NetSafe model utilises a model for the estimation of accident rates and frequencies. The accident rates are modelled in terms of various road and environmental characteristics. These are not the only factors that affect accident rates, but for highway evaluation and analysis, a proportion of the accident rates can be explained in terms of these road-related factors.

Highway safety assessments may be undertaken for various purposes, such as the following:

a) On a network level, the assessments can be undertaken to identify and prioritise hazardous locations on the road network and where road safety improvements are likely to be the most beneficial.

b) The assessment of a proposed geometric design of a road to identify possible hazardous locations.

c) The cost-benefit analysis of alternative road improvements.

## 9.2 NETSAFE BACKGROUND

The NetSafe Highway Safety Model was developed by SANRAL as a methodology for the estimation of accident rates for use in the safety assessments of roads as well as the cost-benefit analysis of road improvements. The model utilises mathematical models for the estimation of expected accident rates and frequencies.

This document contains details of a proposed upgraded version of the NetSafe methodology. The proposed upgrade was developed on the basis of considerably more South African accident data than what was previously available and the upgraded version is therefore considered to be more representative of South African conditions. The upgrading also includes further refinements of the accident prediction models aimed at a more detailed analysis of road safety improvements.

The document provides a broad overview of the proposed upgraded methodology, including the models and formulae used for estimating accident rates. The parameters of the models are not provided in this document but are provided in an accompanying parameter spreadsheet. Software that implements the methodology may either directly access this spreadsheet or import the parameters from the spreadsheet.

The upgrade in NetSafe to version 3 is based on an improved conceptual accident model, given considerably more South African accident data were available to develop the severity models. Although still limited, it was possible to significantly improve the accident models based on the data. More work will be required in future to further improve the model, but it appears if it has now reached a level where it can be used to identify some (but not all) hazardous locations on a road network. With further development, it should be possible to expand the capabilities of the model to identify such locations.

## 9.3 NETSAFE THEORIES

NetSafe 3 was used to develop the Risk Assessment Analysis included in this project. All background and theories are available in the NetSafe 3 document, *Proposed upgrading of the NetSafe Highway Safety Model Version 3,* dated December 2021.

## 9.4 RISK ASSESSMENT PROCEDURE

### 9.4.1 Introduction

Adopting a safe system approach to road safety recognises that humans as road users are fallible and will continue to make mistakes and that the community should not penalise people with death or severe injury when they make mistakes. Therefore, roads (and vehicles) should be designed to reduce the incidence and severity of crashes when they inevitably occur in a safe system.

The safe system approach requires:

Designing, constructing and maintaining a road system (roads, vehicles and operating requirements) so that crash-generated forces on the human body are generally less than those resulting in fatal or debilitating injury;

Improving roads and roadsides to reduce the risk of crashes and minimise harm: measures for higher-speed roads include dividing traffic, designing 'forgiving' roadsides and providing clear driver guidance. In areas with large numbers of vulnerable road users or substantial collision risk, speed management supplemented by road and roadside treatments is crucial for limiting crashes; and

Managing speeds and taking into account the risks on different parts of the road system.

### 9.4.2 Contribution of Roadside Design to Road Safety

Many crashes on road networks, particularly in rural areas, involve run-off-road crashes. The design of the roadside features within clear zones either adversely affect road safety or contribute to a safer environment for all road users. The prime road environment safety objective is to reduce crashes and casualties by improving the road environment and traffic management.

The sides of rural roads have to accommodate various features and infrastructure such as open drains, traffic signs and their supports, and road safety barriers, while urban roads usually have to accommodate paths, public utilities, landscaping and other facilities. All roadside features and infrastructure should be designed to support the safe systems approach by minimising the roadside risk for errant drivers at greenfield sites. Therefore, road designers and practitioners can significantly contribute to crash reduction by applying best practices in the design of roadsides.

### 9.4.3 Risk Assessment Approach

The theories and models in NetSafe 3 are now developed to identify some (but not all) hazardous locations on a road network; It should now be possible to implement NetSafe 3 on SANRAL's system.

However, the spreadsheet application, RAPSA, was developed for this project analysis and can be used for risk assessment on either uniform sections on a project or single positions.

RRS systems ruled by the policy are first implemented during the design process, followed by analysing the remainder of situations via the RAPSA. (See the first decision yellow block in Figure A1).

The NetSafe network procedure is illustrated in Figure A2. (Symbols correspond with NetSafe document):

$N_i$ = Estimated number of accidents on the road section (per annum);

$AADT_{Dir}$ = Annual Average Daily Traffic per direction of travel;

$\Delta L$ = Length of the road section (m);

$R_L$ = Accident rate for length-based factors (accidents per million vehicle–km); and

$R_P$ = Accident rate for point-based factors (accidents per million vehicles).

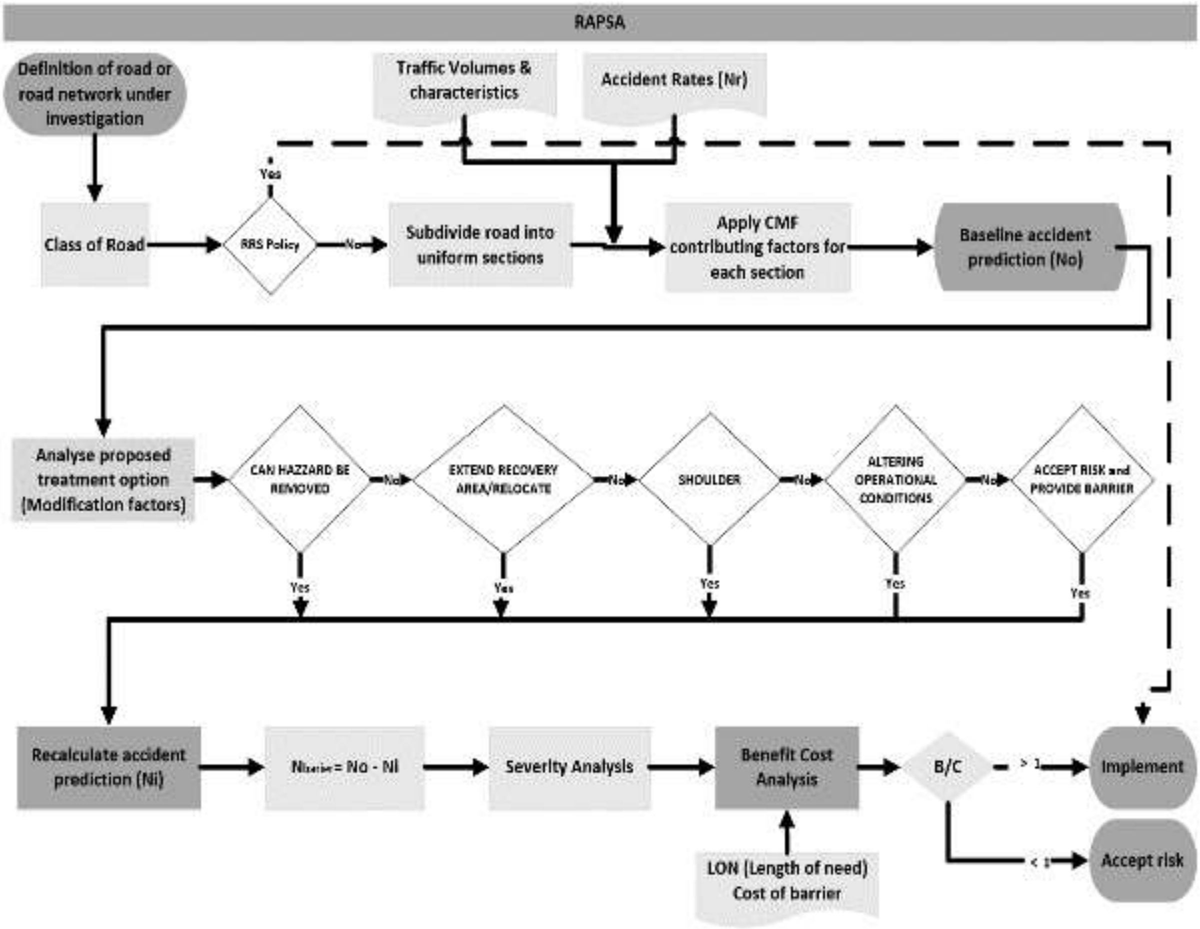


Figure A1: Risk Assessment Procedure

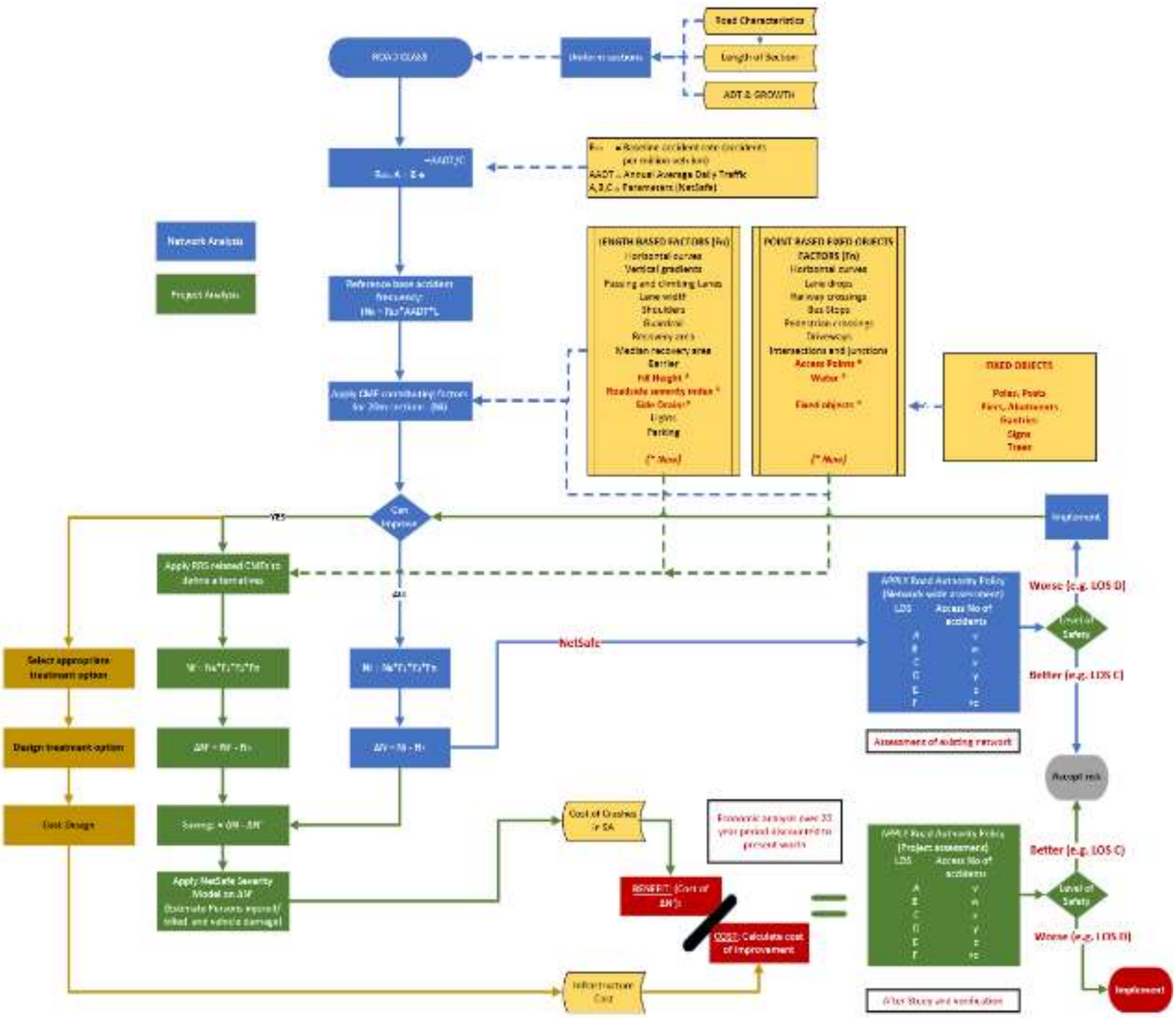


Figure A2: NetSafe network analysis process (See NetSafe 3 for more detail)

### 9.4.4 Crash Reduction

Almost all crashes could have been prevented if the involved persons acted differently, which does not mean that the most effective way to reduce crashes is to alter people's behaviour or tendency to make errors. Effective action must aim jointly at the human element, vehicle and road. Road design can reduce the incidence of human error and the chance of a human error ending up as a crash. It can also ameliorate the severity of crashes initiated by human error.

It is not only the car driver's safety that should be considered but also that of other road users such as pedestrians, cyclists and motorcyclists, and persons occupying properties that traffic crashes might impact.

Road and roadside design for errant vehicles should involve:

A design process that considers the safety of all road users and produces a forgiving road environment;

Design to keep vehicles on the road;

An assessment of the roadside and appropriate action to reduce the risks of roadside hazards through their removal or mitigation;

Provision of road safety barriers through a risk assessment process; and

Choice of road safety barriers through a rigorous acceptance process.

These requirements are essential to provide the safest possible environment for all road users.

### 9.4.5 Risk

Road design aims to achieve a reasonable and economic balance between the assessed risks of hazardous consequences and the measures needed to mitigate those risks.

Most risks, or a combination of risks, can be treated differently. The choice of treatment methods should aim to provide a cost-effective solution consistent with reducing the risk of impacting a particular hazard or hazards. Sometimes, several smaller and cheaper treatments may be just as effective as a single larger treatment, which is more expensive.

The systematic approach to risk reduction in design involves:

- Reducing the inherent hazard;
- Preventing an incident; and
- Limiting damage.

#### 9.4.5.1 Reduce Inherent Hazard

An inherently safe design aims to either eliminate hazards or ensure that the level of roadside risk to road users is very low. While the risk associated with hazards can be reduced through engineering treatments, it should be understood that these treatments may also be hazardous to the occupants of errant vehicles.

For the following reasons, the elimination of hazards should always be preferred to adding safety devices and other layers of protection to make the hazards safer:

Although the severity of an impact with the device or treatment may be less than an impact with the hazard that is being shielded, a hazard is still present; and

There is always the potential for a crash due to simultaneous failure of several layers of protection or the degradation of the layers of protection in the future.

An inherently safe design is better than the use of safety devices (e.g. adding road safety barriers) that can be hazardous to road users and can also add significant maintenance costs over the operational life of the road. It should be understood that safety barriers and other safety devices are also a form of roadside hazard. They can significantly damage errant vehicles, injure the occupants, and be particularly severe with errant motorcyclists. Therefore, they are used to reduce the inherent hazard and should only be used where less severe treatments are impracticable.

While inherent safety represents the first and most desirable way to manage risk, preventing incidents and minimising damage in a crash can also be used effectively to reduce risk.

#### 9.4.5.2 Prevent an Incident

Prevention of an incident is the second step in balanced risk reduction. In transport operations, crashes usually arise because of loss of control and/or containment (a hazardous material or vehicle). Therefore, preventing the loss of control or containment is effective risk control. Matching horizontal curve radii to the operating speed is an example of incident prevention.

#### 9.4.5.3 Limit Damage (Severity)

If a vehicle leaves the road and there is a hazard present that cannot be removed, the hazardous consequences of an incident can be limited, often through protection systems. The use of a road safety barrier to reduce impact severity is an example of limiting damage, as is the choice of a barrier that results in a less severe impact for vehicle occupants during a crash.

Protection systems can be put in place to protect against hazardous consequences if an incident occurs. Protection systems provide a backup when normal facilities for control or containment fail (i.e. when prevention of the incident fails). Road safety barriers are an example of a protection system.

## 9.5 OPERATING RAPSA

### 9.5.1 Netsafe Analysis Process

It is important to understand the operation of the NetSafe model. The model process (Figure A3) can be summarised in the following steps:

- Identify uniform sections;
- Calculate a baseline accident rate by the accident prediction model;
- Identify accident crash contributing factors for each section. Crash modification factors are divided into length and point-based factors;
    - LENGTH-BASED FACTORS (Fn)
        - Horizontal curves;
        - Vertical gradients;
        - Passing and climbing lanes;
        - Lane width;
        - Shoulders;
        - Recovery area;
        - Guardrail;
        - Median recovery area;
        - Barrier;
        - Lights;
        - Parking;
        - Fill heights;
        - Road Severity Index; and
        - Side drains.
    - POINT-BASED FIXED OBJECTS FACTORS (Fn)
        - Horizontal curves;
        - Lane drops;
        - Railway crossings;
        - Bus stops;
        - Pedestrian crossings;
        - Driveways;
        - Intersections and junctions;
        - Access points;
        - Water; and
        - Fixed objects.

- Estimate Severity;
- Calculate a Road Safety Index. The safety index is determined as the excess number of equivalent accidents over a section of road; and
- Calculate Equivalent Accident Numbers. These numbers are obtained by weighing factors to account for different severity levels.

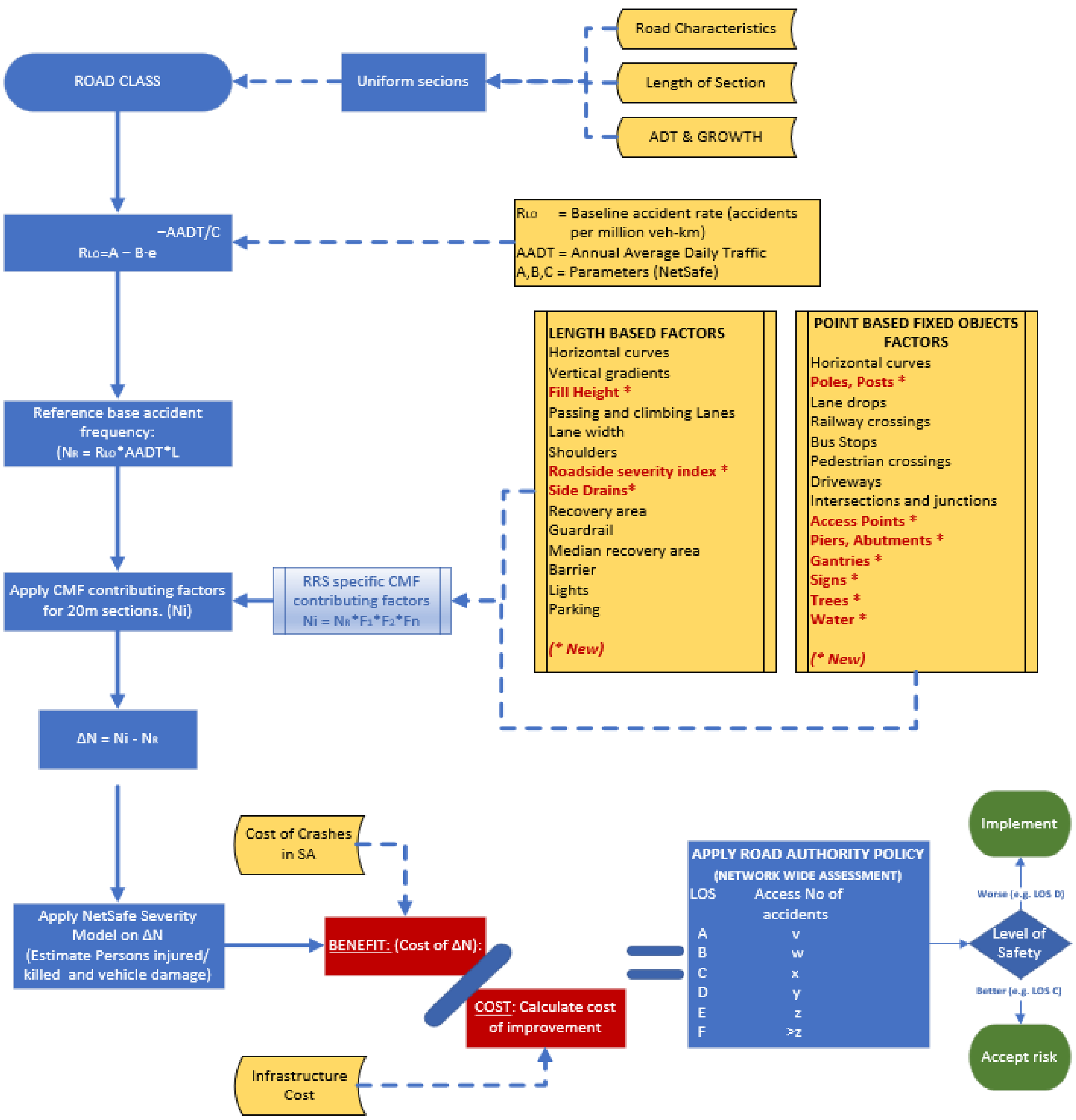


Figure A3: RAPSA analysis process. Factors to be selected via input data.

### 9.5.2 Operating RAPSA

The application has four sheets.

- An opening page
- Notes page

  This page provides basic reference notes for completing the analysis.
- Form page
  - This page is the data input page; the page must be completed for each uniform section;
  - Complete the basic information on the page;
  - Fill all the share fields of uniform sections;
  - Copy form for the number of uniform sections, menu item, left top of the page;
  - Fill each uniform section's unique information;
  - Run the NetSafe Model with the 'NetSafe Model' option. (NetSafe is programmed in visual basic in the application and will only run once the option is chosen) ; and
  - Analyse and compare results.
- Parameters.

All NetSafe Safety Model Parameters are summarised in the spreadsheet over page.

## 9.5.3 RAPSA Input Sheet

**NetSafe Accident Prediction Model**
**Homogeneous Sections**

| Data Item | Direction 1 | Direction 2 | Notes |
|---|---|---|---|
| Road Authority | Road authority name | | |
| Engineer | Engineer name | | |
| Road Number & Name | Road number and name | | |
| Destinations in two directions | Destination 1 | Destination 2 | |
| Year of Analysis | 2021 | | |
| Project/Alternative design description | Project/Alternative design description | | |
| Begin section description | Begin section location | | |
| End section description | End section location | | |
| Start & End Km Distances (Approximate) | 10.100 | 10.200 | Not per direction |
| Length of homogeneous section (m) | 1 | | |
| Road type | Two-Lane Paved | | |
| Functional & RAM Classification | Class 2 | RAM Class 1 | |
| Land Use Left & Right | Rural | Rural | |
| Urban/Rural Classification | Rural Road Class | | Determined by NetSafe |
| Year of traffic count | 2021 | | |
| AADT (Two Directional) & Percent Heavy | 1200 | 15% | |
| Growth & Growth Reduction Rates (Per annum) | 3.50% | 2.50% | Growth Rate in year n = Growth x $(1 - Reduc)^n$ |
| Avg Follower Density (Followers/km/lane) | 5.0 | 5.0 | Per direction |
| Average Speed Light vehicles (km/h) | 110 | 110 | Per direction |
| Horizontal Curve Radius (m) & Direction | | | |
| At start or inside of curve (Y/N) | | | Per direction |
| Gradient Pos upgrade, Neg downgrade | 0.0% | | |
| Number of lanes (excl auxiliary turning lanes) | 1 | 1 | Per direction |
| Lane change, Number of lanes after change | 1 | 1 | Per direction |
| Average lane width per direction (m) | 3.650 | 3.650 | Per direction |
| Paved outside shoulder width (m) | 1.500 | 1.500 | Per direction |
| Paved median shoulder width (m) | | | Per direction |
| Median width between paved shoulders (m) | | | Median data only for divided roads |
| Median length hazard classification | | | Per direction |
| Median clear width (m) from shoulder edge | | | Per direction (Note: Measured from shoulder edge) |
| Median slope in clear width (1:S), Neg down, Pos Up | | | Per direction |
| Median point hazard classification | | | Median point hazard description |
| Median point hazard visibility | | | Per direction |
| Median point hazard offset (m) from shoulder edge | | | Per direction (Note: Measured from shoulder edge) |
| Roadside length hazard classification | Medium Severity | Medium Severity | Per direction |
| Roadside clear width (m) from shoulder edge | 10.0 | 10.0 | Per direction (Note: Measured from shoulder edge) |
| Roadside slope in clear area (1: S), Neg down, Pos up | -1.50 | -1.50 | Per direction |
| Roadside point hazard classification | No Hazard | No Hazard | Roadside point hazard description |
| Roadside point hazard visibility | No Hazard | No Hazard | Per direction |
| Roadside point hazard offset (m) from shoulder edge | 0.0 | 0.0 | Per direction (Note: Measured from shoulder edge) |
| Road reserve fence type | Cattle Fence | Cattle Fence | Per direction |
| Intersection Control Type | | | |
| Intersection Layout and Cross road AADT | | | |
| Number of approaches with left/right turn lanes | | | Exclude stop controlled approaches |
| Property Accesses (Number) - Farm/Residential | 0 | 0 | Per direction |
| Property Accesses (Number) - Developments | 0 | 0 | Per direction |
| On-road parking | No Parking | No Parking | Per direction |
| Road lighting | No Lighting | | Per direction |
| Pedestrian Occurance on Road | Rare | Rare | Per direction |
| Cylist Occurance on Road | Rare | Rare | Per direction |
| Animal Occurance Adjacent to Road | Low | Low | Per direction |
| Pedestrian Accommodation | Walk on Shoulders | Walk on Shoulders | Per direction |
| Cyclist Accommodation | Cycling on Shoulders | Cycling on Shoulders | Per direction |

| Base Safety Analysis | Totals for Two Directions | Present value is total discounted value |
|---|---|---|
| Number of accidents in year of analysis | 0.00 | Accidents/Year |
| EAN in year of analysis (Per Capita GDP) | 0.01 | EAN/Year |
| Present EAN value, analysis period (Per Capita GDP) | 0.05 | Present value of EAN |

| Safety mitigating measures in direction | Direction 1 | Direction 2 | Reduction of present values of EAN (neg if it increases) |
|---|---|---|---|
| Roadside guardrail or barrier (at shoulder edge) | 10.76 | 10.76 | Per km guardrail/barrier |
| Roadside point hazard - Reducing severity to low | | | |
| Roadside point hazard - Removing point hazard | | | |
| Median guardrail or barrier (at shoulder edge) | | | Per km guardrail/barrier |
| Median point hazard - Reducing severity to low | | | |
| Median point hazard - Removing point hazard | | | |

# 10 ANNEXURE B: STRUCTURAL DESIGN OF BRIDGE BALUSTRADES

Structural design of bridge balustrades to TMH 7 Code of Practice for the Design of Bridges and Culverts in South Africa 1981

(b) *On Class I balustrades, viz. those required to resist impact by vehicles on highway bridges:* The force $F_b$ shall be 50 kN and shall be applied laterally, at or below a limiting height of 700 mm above the level of the road adjacent to the kerb for a kerb width of 150 mm, increasing linearly to a limiting height of 900 mm for a kerb width of 450 mm. For kerb widths greater than 450 mm, the limiting height shall remain at 900 mm (see Fig. 5).

(b) ON CLASS I BALUSTRADES

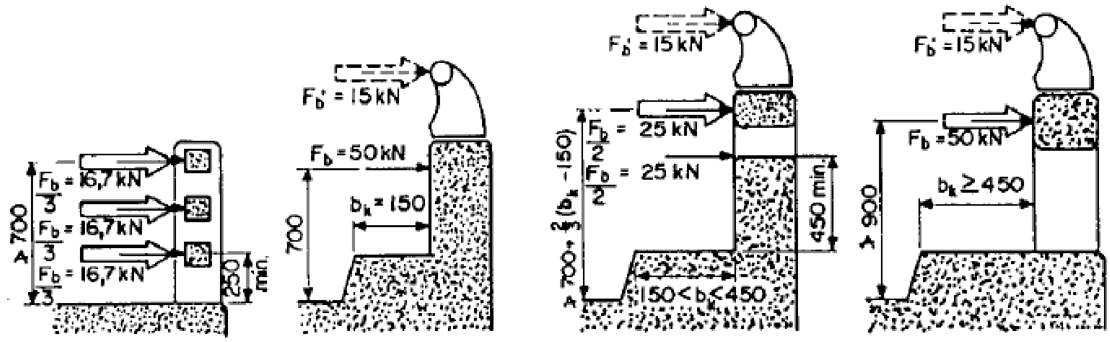


FIG. 5

(c) *On Class II balustrades, viz. those required to contain only pedestrians on highway or pedestrian bridges* (see Fig. 6):

(i) In the case of balustrades on pedestrian bridges, the distributed force $q_p$ shall be 1,5 kN per linear metre acting transversely, together with a simultaneous vertical force of 1,5 kN/m acting vertically, on each longitudinal member. A transverse force of 1,5 L kN, where L is the post spacing in metres at the centre of the upper rail, shall act on each post independently of the longitudinal member forces specified. The characteristic moment for longitudinal railings shall be taken as 0,1 $q_pL^2$ at the centre of the panel and at the posts.

(ii) In the case of balustrades on highway bridges, the forces shall be identical to (i) above, excepting that the forces shall be increased from 1,5 to 4,5 kN/m for longitudinal members and from 1,5 L to 4,5 L for posts (see Fig. 7). For concrete parapet walls, a transverse force of 15 kN shall act at the top of the wall and shall be spread longitudinally at an angle of 45 degrees to the horizontal for the purpose of determining the length of wall resisting the force (see Fig. 8).

(c) ON CLASS II BALUSTRADES

(i)

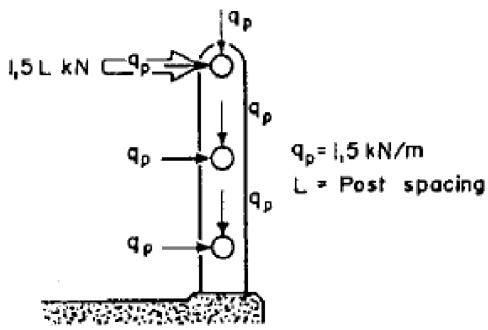


FIG. 6

(ii)

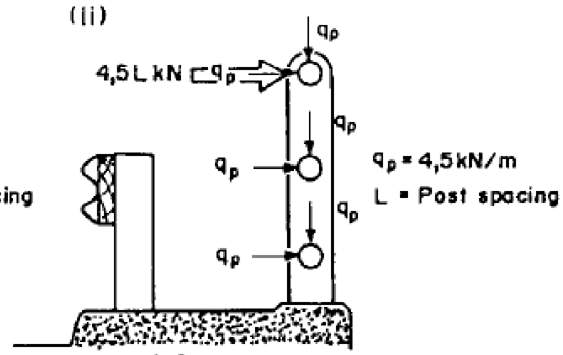


FIG. 7

CONCRETE PARAPET WALLS

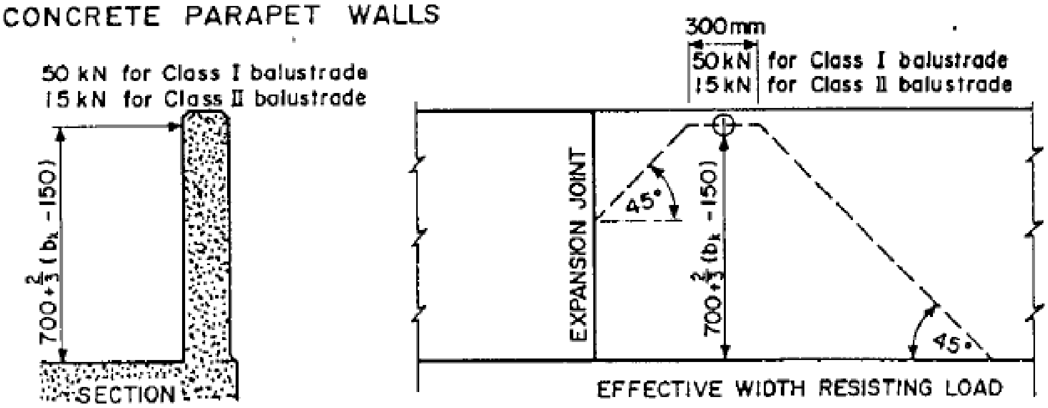


FIG. 8