Revision of Austroads Crash Barriers Manual

Philip Roper, Fiona Green, Michael Tziotis and Gary Veith
ARRB Transport Research

Abstract

The use of guard fencing is a key means by which roadside hazards are safely managed. To assist road designers and road safety practitioners, in 1987 the National Association of Australian State Road Authorities (NAASRA, now Austroads), released a guide for the provision of safety barriers.

Since that time major developments have taken place in improving the design of barriers and crash cushion systems worldwide. New types of barriers, such as flexible systems incorporating wire ropes, have also come into use in many areas. Furthermore, it has come to light that some barrier treatments once thought to provide protection (as detailed for use within the NAASRA publication) have since proven themselves to be hazardous (eg. turned down end treatments, which can result in impacting vehicles 'vaulting' the barrier).

This report presents work to date on a draft Austroads Guide for the installation and maintenance of roadside safety barriers. Research to this stage has involved a literature review to identify best practice worldwide and a summary of current practice across Australasian road authorities.

1 Introduction

ARRB Transport Research Ltd (ARRB TR) was commissioned by Austroads to conduct a review of the 'Safety Barriers' guidelines published by the National Association of Australian State Road Authorities (NAASRA) (1987). The review seeks to incorporate the best practices for the design and installation of safety barrier systems that will result in a reduction in the severity of run-off road crashes.

1.1 Background

The use of crash barriers is a key means by which roadside hazards are safely managed. To assist road designers and road safety practitioners, the National Association of Australian State Road Authorities (NAASRA, now AUSTROADS), released a guide for the provision of Safety Barriers.

Since that time major developments have taken place in improving the design of crash barriers and crash cushion systems worldwide. It has also come to light that some barrier treatments once thought to provide protection (as detailed for use within the NAASRA publication) have since proven themselves to be hazardous (eg. turned down end treatments, which can result in impacting vehicles 'vaulting' the barrier).

In recognition of the need to review and update the current Austroads publication, the Austroads Road Traffic Reference Group raised the matter with the Austroads Road Safety Group to commission a review as part of the Austroads Road Safety Core Program.

Fixed roadside objects, such as trees, poles, culverts, fences and guardrail, account for approximately 30-40% of fatalities and serious injuries on Australian roads (Kloeden & McLean 1999; Ogden 1994; Pirrotta 1999). Pirrotta also suggests that 9% of fatal and serious injury single-vehicle crashes are a result of impacts with embankments and 15% of fatal and serious injury single vehicles crashes involve the vehicle overturning, possibly as a result of impacts with embankments, roadside objects, batters or drains.

Notably, 3% of fatal and serious injury single vehicle crashes are as a result of collisions with guard rail (Wilson, Corben & Narayan 1999; Pirrotta 1999). The implication is that guardrail, or safety barrier systems, although installed to protect vehicles from collision with roadside hazards, are actually roadside hazards themselves. The need to ensure barrier systems are only installed when necessary is thus highlighted.

1.2 Objectives

The objectives of the review are:

- to review and update the previously released Austroads series publication, Safety Barriers (1987);
- to develop guidelines that reflect best practices in the design and installation of crash barriers systems;
- to promote the use of current best practices across Australia , that will ultimately provide a consistent approach to the use of crash barrier systems across jurisdictions.

1.3 Scope

The review comprises six parts:

1. Literature review and Internet search on current best practices in crash barrier systems.
2. Identify current practice in all Australasian jurisdictions in the selection and use of crash barriers.
3. Review NAASRA (1987) and develop a set of draft guidelines, reflecting the information gathered in Parts 1 and 2.
4. Prepare a final draft of the guidelines.
5. Prepare a final set of guidelines.
6. Undertake a series of workshops in Australia and New Zealand to release the revised draft guidelines.

This report presents a summary of work to date on sections 1 and 2 of the review. Writing of the new guidelines is currently in progress.

2 Guidelines in use by Australasian road authorities

Australian / New Zealand Standard "AS/NZS 3845:1999 Road Safety Barrier Systems" details various methods of roadside hazard protection and provides direction on the correct use of the different systems. The Standard has been the basis for a number of guidelines written by individual road authorities for use within their jurisdiction.

Prior to the publication of this Standard, NAASRA's 1987 guidelines were the only national guide to the treatment of roadside hazards. Various jurisdictions have written their own guidelines, drawing on information from the NAASRA guide, the Standard and other international publications, most frequently from the United States. The NAASRA publication has largely been superseded by the road authorities' own guidelines. The guidelines provide only three types of barrier system options:

1. Blocked-Out Steel W-beam guard fence (strong-post);
2. New Jersey Concrete Barrier; and
3. New York Steel Box beam guard fence.

Other systems are also briefly mentioned with only minimal detail provided, ie weak-post W-beam guard fence, Thrie beam fence and variable stiffness guard fences. The latter types of guard fence identified are not promoted for use because of the high cost associated with their installation and maintenance. For each type of barrier a brief description is given of the features of the barrier, such as placement, transition with other barrier types, and end terminals. The guidelines, whilst providing a general description of crash cushions, do not specify cushion types.

3 Comparison of Australasian guidelines

Various road authorities' guidelines address a range of different aspects of the selection, installation and maintenance of safety barrier systems. Some requirements and recommendations overlap between different guidelines, and others are mentioned in only some of the guidelines. In this review the NAASRA publication has been compared with current guidelines and worldwide best practice to identify sections in need of revision.

3.1 Evaluation of Collision Risk

The installation of any crash barrier is an attempt to reduce the incidence or severity of collisions with a roadside hazard. Before the decision to install a barrier is taken, it is necessary to investigate other methods of reducing the risk of collision with the hazard. If the hazard cannot be removed or redesigned and the road alignment or road condition cannot be improved to reduce the incidence of vehicles leaving the road, then a crash barrier may be an appropriate choice of treatment.

NAASRA's 1987 guide advises that alternative measures be exhausted before a crash barrier is installed because any crash barrier will be hazard in itself.

3.2 Clear Zone Requirements

Part of the initial decision to install a roadside safety barrier is consideration of the distance between the edge of the pavement and the hazard to be protected.

The literature regarding safety barriers consistently reaffirms the need to provide safety barriers only when warranted as a barrier becomes another potential roadside hazard as soon as it is installed. To assist practitioners in determining when the risk of installing a barrier will reduce the severity of a crash rather increase the risk, a number of tools have been developed. A summary of the installation considerations for roadside objects that appear in the Australian Safety Barriers guidelines (NAASRA 1987) is listed in Table 1.

Table 1: Installation Evaluation Summary

Recommendations	**High AADT>3000**	**Intermediate AADT 1000-3000**	**Low AADT<1000**
Clear width – remove or shield all hazards	7-10 metres	5-7 metres	Up to 5 metres
Recovery-width –shield major hazards	12 metres	7-10 metres	Up to 7 metres, obtain a consistent roadway environment by shielding exceptional hazards
Avoid installing new hazards	12 metres plus	Within 7 metres	Adjacent to roadway

(Source: NAASRA 1987 Table 3-2.)

Figure 1 below depicts the considerations for embankments (cut or fill) as detailed in the 1996 AASHTO publication.

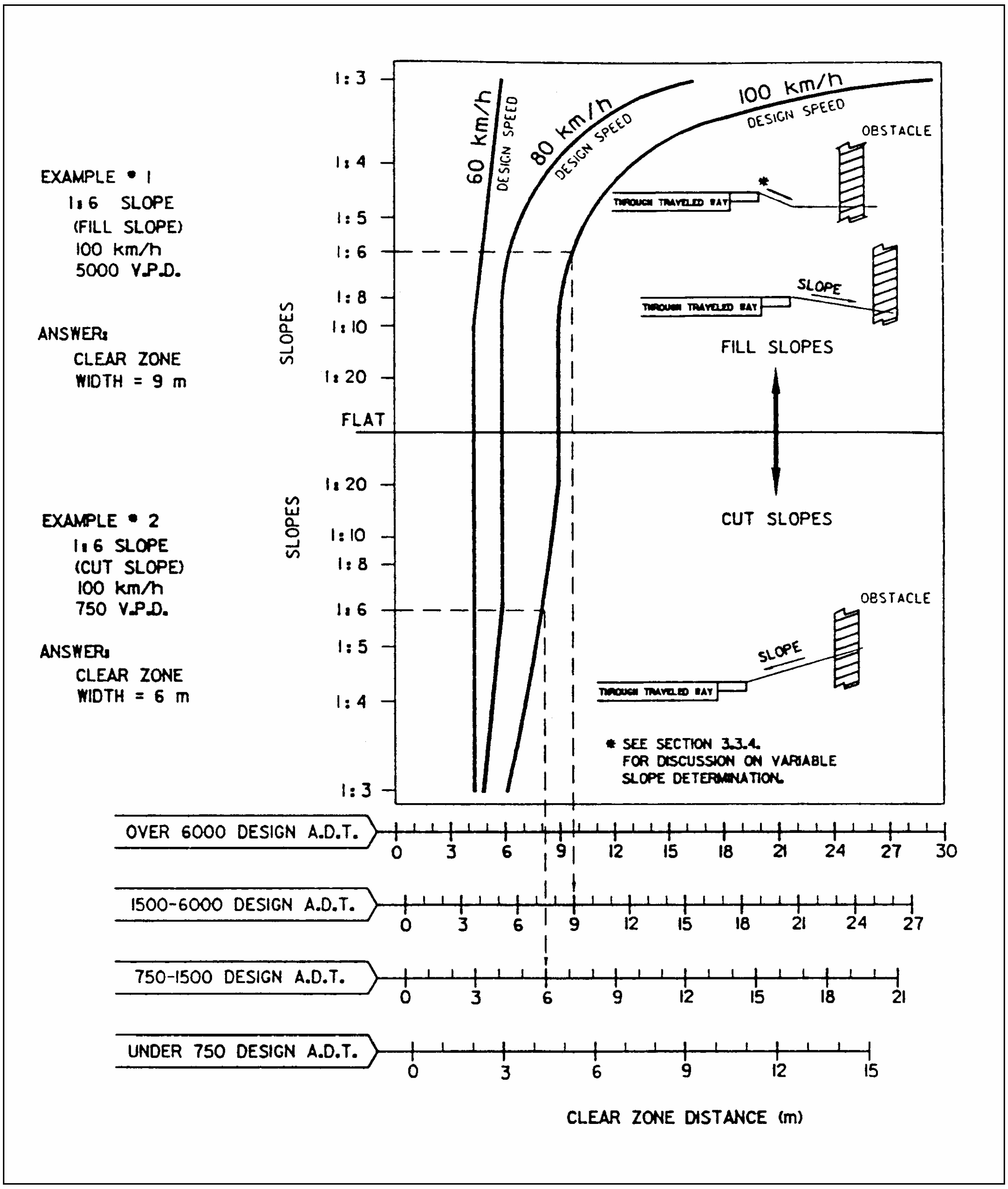

Figure 1: AASHTO 1996 Clear Zone Chart
(Source: AASHTO 1996, Figure 3.1.)

This guide to clear zone widths has the advantage of catering for various travelling speeds and is broadly applicable to treatments in all Australasian jurisdictions, with some guidelines giving more information on the topic than others.

Queensland and Western Australia use the AASHTO 1996 clear zone chart while New South Wales and Victoria use their own charts. The New South Wales chart works on a similar basis to the AASHTO chart, providing ranges of clear zone widths depending on slope angles, speeds and AADTs. The Victorian chart provides a clear zone width based on AADT and speed and then provides calculations to estimate the *effective* clear zone width when slope angle is taken into account. All methods cater for differences between embankment slopes and cutting slopes (where the roadside drops away or rises up from the road respectively). Guidelines for Tasmania and the Northern Territory refer practitioners to the AASHTO chart.

3.3 Length of Need

Length of Need is the term used to describe the length of barrier needed to shield a hazard. Calculation of the length of need is discussed in various State guidelines but is left out of the Australian Standard. The Standard deals principally with correct construction and maintenance of the system, leaving the decision on the length of the system up to the practitioner. The basis of the estimation of length of need, as used in each jurisdiction, is summarised in Table 2 below.

Table 2 – Length of Need requirements of various guidelines

	Method of calculating Length of Need
AS3845	Not specified

	Method of calculating Length of Need
New South Wales	Leading angles specified for 85th and 15th percentile speeds at different speed limits:
Victoria	Runout length specified for various speeds and AADTs. Length of need found by using runout length, hazard position and lane widths
South Australia	Runout lengths specified for various speeds
Queensland	As for New South Wales (leading angles specified)
Tasmania	Not specified
Northern Territory	Not specified
New Zealand	As for Victoria (runout lengths specified)
Western Australia	Not specified but guide refers to NSW RTA document for details

The NAASRA guidelines use the run-out length method of calculating length of need.

3.4 Types of Barrier

Table 1 below presents a comparison of the types of barrier allowed by the guidelines in various jurisdictions. The first row of the table shows the requirements of AS3845, on which some of the other guidelines' recommendations are based.

"Road safety barriers embodying tensioned wire ropes" is the term used in AS3845 to describe all non-rigid roadside crash barriers that use wire ropes, due to the emergence of some types of barrier that use both steel beams and ropes as horizontal members in the same barrier. Where "wire rope" is specified in the following table, it refers to barriers in which horizontal members are made only of wire rope. Barriers utilising a combination of wire rope and steel beams are not yet in use in Australia and are not mentioned in any current Australasian guidelines other than the Standard. The cable in a breakaway cable terminal (BCT) is not classed as a tensioned wire rope because its purpose is not to act as a barrier, but act as an anchorage for steel beam barriers.

Table 2: Barrier types allowed by various guidelines

	Rigid Barriers	Semi-Rigid Barriers*	Flexible (Non-Rigid) Barriers
AS3845	• Type F • Vertical Concrete Barrier • Other as tested	• G4 W-beam • G9 Thrie beam • MB4 double-sided W-beam • MB9 double-sided Thrie beam	Not specified
New South Wales	• Tri-bloc • Various other concrete profiles	• G4 W-beam • G9 Thrie beam	• Wire rope
Victoria	• Vertical constant shape • Type F • New Jersey Barrier (no longer recommended)	• G4 W-beam	• Wire rope
South Australia	• Type F	• G4 W-beam	• Wire rope
Queensland	• Single slope • Type F if joining existing Type F barrier	• G4 W-beam • G9 Thrie beam	• Wire rope
Tasmania	• Concrete barrier (no shape specified)	• G4 W-beam • G9 Thrie beam • Steel box beam	• Wire rope
Northern Territory	See AS3845	See AS3845	See AS3845
New Zealand	None	• G4 W-beam • G9 Thrie beam	None
Western Australia	See AS3845, plus: • Type F • Tri-bloc • Constant shape	• Water-filled barriers • G4 W-beam • G9 Thrie beam	• Wire rope

Semi-rigid barriers are referred to as "non-rigid" in the Australian Standard. Other guidelines refer to the same types of barriers (ie. W-beam) as semi-rigid, and reserve the term non-rigid for wire rope safety barriers and crash cushions.

AS /NZS 3845:1999 describes the tests required to be successfully completed before a barrier system can be used on the Australian road network. The standard is primarily based on the US standard barriers, NCHRP 350 (TRB 1993). The European standard (EN 1317 1998) is also similar to the US standard.

The Australian and European standards consider crash barriers and crash cushions, whilst the US standard also considers support structures, work zone traffic control devices, breakaway utility poles and truck mounted attenuators.

3.5 Lateral Space Required for Barrier Installation

The deflection of a barrier upon impact must be considered during selection of a treatment for a site. If there is insufficient room for the barrier to deflect under vehicle impact without colliding with the hazard, a more rigid barrier must be used. The AS3845 document does not specify standard lateral clearances but states that any barrier used must be of adequate strength to prevent deflection that would allow contact with the hazard.

3.6 Terminal Treatments

A variety of terminal treatments are available for guard fence. Both gating and non-gating terminals can be used, depending on the requirements of the particular installation.

Gating terminals are designed to allow an errant vehicle to break through the end of the barrier and come to rest safely in a run-off area. Adequate run-off space is required to ensure that the vehicle can stop safely without hitting any other components of the barrier or hitting the hazard that the barrier is designed to protect.
Non-gating terminals have a re-directive role and aim to guide an errant vehicle to a safe stop without it breaking through the barrier.

The NAASRA guidelines describe terminal details for W-beam guard rail and New York Box Beam guard fence. The guidelines recommend that drum-end terminals (breakaway cable terminal) be used in W-beam installations and concrete barriers be terminated either by the use of other guard fence leading into the concrete barrier or by burying the end of the barrier in a cut face.

The Australian Standard lists two types of end terminals as suitable for use in semi-rigid guard fence installations: Slotted Breakaway Cable Terminal (which have replaced Breakaway Cable Terminals due to the unsuitability of BCTs for impacts by light vehicles) and Modified Eccentric Loader Terminals (MELT). Various other types of energy absorbing re-directive and non-redirective end treatments are available from a number of manufacturers and the Standard instructs that such terminals must be installed in accordance with manufacturers' recommendations.

Listed below in Table 3 are the end treatments specified for semi-rigid and non-rigid guard fencing in the various guidelines. End treatments for rigid barriers are either crash cushions or transitions to semi-rigid barriers. These are dealt with in other sections of the guidelines.

Table 3: Terminal treatments

	Terminals recommended
AS3845	• W-beam: Slotted Breakaway Cable Terminal (SBCT), Modified Eccentric Loader Terminal (MELT)
New South Wales	Various types with table of recommended uses
Victoria	• Wire rope: Brifen Wire Rope Terminal, FlexFence Wire Rope Terminal • W-beam: Various types including SBCT (called BCTA by VicRoads), ELT, MELT • Concrete barrier: burial in cut face
South Australia	• W-beam: BCT, burial in cut face • Concrete barrier: burial in cut face, crash cushion, W-beam BCT

Queensland	• W-beam: MELT • Concrete barrier: QuadTrend 350
Tasmania	• W-beam: SBCT
Northern Territory	See AS/NZS 3845
New Zealand	Any compliant with NCHRP 350 Test Level 3. Excluded: BCT, MELT
Western Australia	See AS/NZS 3845

3.7 Transition Treatments

In circumstances where a rigid barrier is required, for example on a bridge or at the edge of an embankment with little shoulder space, there will often be a need to connect the rigid barrier to a preceding section of semi-rigid or non-rigid barrier.

The general recommendation of the various guidelines is that the transition to a rigid barrier from less rigid barriers must be accomplished smoothly and without allowing impacting vehicles to be snagged on the end of the rigid barrier. The rate of deceleration of the impacting vehicle must not be increased due to the transition. Table 4 below lists the transition instructions of each of the guideline documents.

Table 4: Transitions between barrier types

	Transition methods provided/recommended
AS3845	Progressive stiffening (no barrier types specified)
New South Wales	Not specified
Victoria	Reference to Part 9 of Road Design Guide for W-beam to concrete barrier transition
South Australia	Progressive stiffening (no barrier types specified)
Queensland	Wire rope to W-beam/thrie-beam, W-beam/thrie beam to concrete barrier/bridge end detailed in standard drawings
Tasmania	See NAASRA and AS/NZS 3845
Northern Territory	See AS/NZS 3845
New Zealand	Progressive stiffening (no barrier types specified)
Western Australia	Progressive stiffening (no barrier types specified)

3.8 Crash Cushions

Protection of narrow hazards that are likely to be hit end-on by vehicles requires the use of crash cushions. These devices are designed to crumple in an end-on impact and decelerate a vehicle in a safer manner than would occur if the vehicle had hit the concrete bridge end or gore that the barrier is protecting. Crash cushions are usually designed to perform a re-directive role when struck on the side at angles up to around 20 degrees from parallel. Some types of crash cushion are able to automatically recover a significant portion of their original shape after impact so that they continue to perform adequately until maintenance can be provided.

The range of crash cushions available changes rapidly with new technologies and consequently the types of devices listed in various State and Territory guidelines differ depending on when the guidelines were written. Crash cushions are generally recommended by guidelines on the basis that they have passed the NCHRP 350 Test Level 3 for vehicles up to 2000 kg. The requirement for devices to have passed this test allows the installation of newer, more advanced designs as they become available.

3.9 Motorcycle barriers

One area not covered by the Australian guidelines is the compatibility of barrier systems with unprotected vehicle occupants such as motorcyclists.

ATSB (2000a) data indicates motorcyclist fatalities account for 10% (177) of all fatalities on Australia's roads in 1997. Of this 10%, approximately 5% (ie. 0.5% of all fatalities) are believed to have been as a result of impacting with a barrier (ATSB 2000b, cited Duncan, Corben, Trudesson and Tingvall 2001). Overseas experience indicates slightly higher proportions of injury for motorcyclist impacts with guard fences. In particular, guard fence posts are the main cause of injury, also any protrusions in the surface of the barrier may cause a sliding motorcyclists to be snagged. Safety barriers have shown to be beneficial in protecting car occupants, however consideration of motorcyclists and cyclists in the design and installation of many barrier systems has been neglected (Mount 1998). This is primarily due limited research in this area and also to the low number of these road users amongst the overall road user population. However, it is important to note the motorcyclist and cyclist vulnerability to injury is greater and hence special consideration is necessary.

Methods for testing barriers using dummies have only recently been researched, primarily in Europe (Pieribattetseti & Lescure 1999;). A method of projecting an instrumented dummy into a barrier was developed by the French National Institute for Transport and Safety Research (INRETS). Similar tests have also been developed in Germany to test impact attenuators. The method described has been tested but because the number of crashes of this type are so low it is not possible to make conclusions about the appropriateness of tests at this stage (FEMA 2001). The method was recently trialed in research aimed at encouraging manufacturers to design for motorcyclists as well as motorists. As a result of this research two products have been identified. One, called Moto-rail, is a new barrier system and the other, Moto-tub, is an addition that can be adapted to existing barrier systems.

One simple improvement in barrier design, which reduces the hazard to motorcyclists, is the use of Sigma (Σ), Z or C shaped posts (FEMA 2001) however this is not an ideal alternative as the posts still remain a danger. The Sigma posts have been adopted extensively in Germany and results of analysis indicate a considerable decrease in the level of injury from crashes with this type of barrier (Wink 1996).

Other alternatives include impact attenuators (ie crash cushions) fitted to each post, or an additional W-beam located lower on the posts. The impact attenuators can be made of polystyrene, polyurethane or a similar material. Such devices have been installed in Germany and Austria (Dohman 1987 cited in FEMA 2001).

Wire Rope Safety Fences have been highlighted as a particular concern for motorcyclists. The view held by some riders is that impact with a WRSF would have the effect of slicing the body (Duncan et al 2001; FEMA 2001). The number of accidents involving motorcyclists with these types of barriers is very low so it is difficult to qualify the concerns.

3.10 Work zones

Specific attention to safety barrier installation at work sites will be required in the updated guidelines. Auditing of construction sites by Muthsamy & Kumar (1995) indicated a lack of knowledge about safety barriers and their fundamental design. Some of the problems identified by Muthsamy and Kumar included:

- installations too short to shield errant vehicles from hazard;
- embankment approach to barriers too steep to be effective; and
- ineffective end treatments.

Muthsamy and Kumar's review of construction zones highlighted the deficiencies that exist in terms of barrier systems for work zones. Overseas there has been a considerable amount of work dedicated to identifying appropriate systems and designing traffic management plans in accordance with barrier requirements and work zone safety.

4 Conclusion

Most of the crash barrier guidelines in use by various Australasian road authorities have advanced beyond the standards used in NAASRA's 1987 publication. The Australian / New Zealand Standard for crash barriers has been used together with the contents of AASHTO's 1996 roadside design publication and the results of other international research to provide practitioners with updated information on safer and more efficient roadside hazard protection methods.

Some of the omissions from the NAASRA guidelines include

- Clear zone policies that reflect changes in traffic volumes, in particular proportions of heavy vehicle traffic, and also allowing for the different forces acting on vehicles around curves resulting in altered patterns of movement for errant vehicles around curves.
- Consideration of new rigid, semi-rigid and flexible barrier systems, such as newer profiles of concrete barrier (rigid) and wire rope barriers (flexible) should be included.
- Descriptions of transitions between barrier systems, in particular between rigid and flexible systems.
- Consideration of different types and installation requirements of end terminals, including crash cushions and impact attenuators.
- Removing practices that have been shown to be unsafe through use of barrier systems on the road network. For example, the use of turned-down end treatments for rigid and semi-rigid barrier systems.
- Designing barrier systems with consideration of vulnerable road users, such as pedestrians and cyclists.
- Designing barrier systems to reduce the risk of injury or death for motorcyclists.
- Requirements of barrier systems in temporary situation such as road works.

The guidelines currently used across Australasia are largely in agreement with each other in key areas such as end terminals and barrier shapes. Different methods are used by different documents for determining length of need and clear zone requirements. It will be necessary for the updated Austroads document to take all practices into account. This report provides a basis from which the current practices of Australian road authorities can be assembled, together with other international research, into a revised Austroads guide to crash barriers.

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