Ontario

MINISTRY OF TRANSPORTATION

ROADSIDE DESIGN MANUAL

JULY 2023

HIGHWAY STANDARDS BRANCH
DESIGN & CONTRACT STANDARDS OFFICE

Record of Revisions

This version of the Roadside Design Manual dated July 2023 includes Edition #3 and supersedes the previous edition. Changes from the previous edition are summarized below.

All Chapters

- All references to Design and Contract Standards Office replaced by Highway Design Office
- Existing roadside hardware for which MTO no longer has standards referred to as Legacy Systems

Chapter 1

- Section 1.1 added definition for Dynamic Deflection
- Section 1.2 updated ORSAR collision data to 2019 and NHTSA collision type data to 2020.

Chapter 2

- Erratum: Table 2-4 corrected less than or equal to notation
- Erratum: Table 2-6 corrected less than or equal to notation
- Table 2-11 added gore encroachment length for 130 km/h design speed
- Section 2.3.6 changed 22.5m depressed median to “minimum” from “standard”. Added requirement for median barrier protection for new medians less than 22.5m width. Added requirement that left shoulder be no wider than one 0.25 m increment than adjacent left lane.
- Section 2.3.9 changed curb nomenclature from “barrier”, “semi-mountable” and “mountable” to “Type I”, “Type II” and “Type III” respectively.
- Section 2.3.9 added wording stating that curb does not have redirectional capacity at speeds greater than 10 km/h
- Section 2.3.12 new section covering luminaire supports and high mast poles
- Section 2.4.1 added requirement to policy statement that roadside systems on high-speed roads shall be TL-3 or greater.
- Table 2-15 added runout lengths for 130 km/h design speed.

Chapter 3

- Table 3-1 added encroachment lengths for 130 km/h design speed
- Section 3.3.3 Length of Guiderail System Documentation removed
- Section 3.3.4 (renumbered from 3.3.3) added requirement that existing SBGR runs on high speed roads and all existing 3-cable guide rail are to be replaced

with MASH roadside barrier. Removed guidance on evaluation of existing 3-cable guide rail.

- Section 3.3.3 added Type M SBGR evaluation criteria for existing systems
- Section 3.3.3 re-organized into three sub-sections: 3.3.3.1 Introduction, 3.3.3.2 Legacy Systems and 3.3.3.3 Evaluation Criteria.
- Section 3.3.3.2 introduced terminology for Legacy Systems.

Chapter 4

- Section 4 introduction added note that designers should keep current with standards and specifications between RDM updates
- Section 4 introduction added clarification that systems are not to be modified from standards without the guidance of Highway Design Office
- Section 4.1.2 added paragraph highlighting potential non-intuitive behaviour of roadside systems and reinforced the importance of not making modifications.
- Table 4-1 removed entry for Type M SBGR with ¼ post spacing. Updated working width for Type M SBGR with ½ post spacing.
- Section 4.2.2.1 added information on 1 m pedestrian opening in SBGR
- Section 4.2.2.1 added MASH SBGR structure connection information
- Section 4.2.4 new section added for thrie beam roadside barrier systems including guidance on use on high truck volume roads.
- Section 4.2.4.1 new section for ACP TL-4 roadside barrier
- Section 4.2.4.2 new section for EzyGuard High Containment barrier
- Section 4.4.1.7 new section for MATT Median SBEAT. Existing sections 4.4.1.7 and 4.4.1.8 renumbered to 4.4.1.8 and 4.4.1.9
- Section 4.4.2.7 new section for SMA Hercules crash cushion
- Section 4.4.2.8 new section for Delta crash cushion
- Section 4.4.4 added requirement to replace systems pre-dating NCHRP Report 350 on capital contracts.
- Section 4.5 added note allowing shielding of overhead and cantilever sign supports with a redirective, non-gating crash cushion.

Chapter 5

- Section 5 introduction added note that designers should keep current with standards and specifications between RDM updates
- Section 5 introduction added clarification that temporary barrier systems are not to be modified from standards without the guidance of Highway Design Office
- Section 5.1 changed “front face” to “traffic face”

- Section 5.1.1 added clarification that ministry-approved temporary barriers are required for DBB, DB, P3 and all alternative delivery model contracts.
- Section 5.1.1 changed “Quickchange Movable Barrier” to “Movable temporary concrete barrier”
- Section 5.1.1.1 added section with guidance on the use of temporary barriers to separate opposing traffic flows
- Section 5.1.2 added direction prohibiting the use of precast I-lock Tall Wall barrier in temporary applications.
- Section 5.1.2.2 changed Type M TCB guidance to allow only MASH tested freestanding version on low-speed roads.
- Section 5.1.2.4 added restrained options for Type X TCB
- Section 5.1.2.5 added restrained option for Type Z TCB
- Section 5.1.3 broke section into subsections for different movable temporary concrete barriers.
- Section 5.1.3.2 new section on Reactive Tension System barrier
- Section 5.1.3.3 new section on Flux System
- Section 5.1.4.6 new section on Highway Guard steel barrier
- Section 5.2 changed “front face” to “upstream face” in reference to temporary crash cushions
- Section 5.2.1 listed individual reduced exposure systems in 5.2.1.X subheadings consistent with other similar sections
- Section 5.4 new section for Temporary Work Zone Signs
- Section 5.4.1 new section for skid-mounted temporary sign supports

Appendix A

- No Changes

Appendix B

- Added definitions consistent with updated MTO Design Supplement

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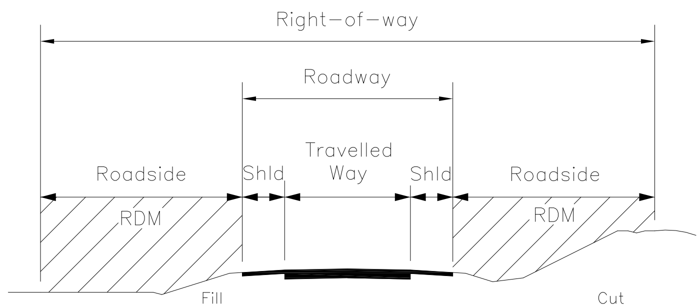
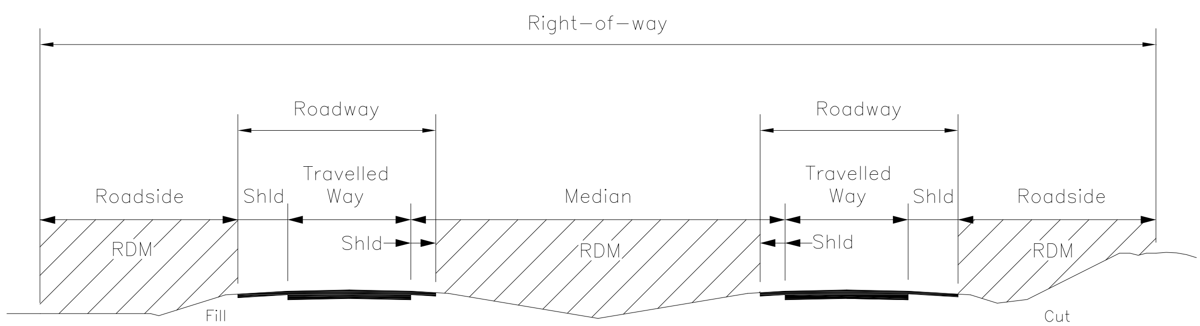
1. Introduction

The purpose of the Roadside Design Manual (RDM) is to provide MTO staff and engineering consultants with updated cost beneficial policies, standards, and guidelines for design of the roadside environment adjacent to the roadway within provincial highway Right-of-Ways (ROW) as shown in Figure 1-1. A comprehensive literature review was carried out during the preparation of the RDM, relying extensively on the American Association of State Highway and Transportation Officials (AASHTO) Roadside Design Guide, United States Federal Highway Administration (FHWA) Memoranda, National Cooperative Highway Research Program (NCHRP) Reports, Midwest States Pooled Fund Program Research Reports, Texas Transportation Institute Roadside Safety Pooled Fund Research Reports, and roadside safety hardware manufacturers, distributors and installers.



Undivided Highway



Divided Highway

Figure 1-1 – Provincial Highway Right-of-Way Components

Although the RDM is issued primarily for the direction and guidance of MTO staff and engineering consultants for design of provincial highway projects, it may also be used as a design guideline by other road authorities in Ontario. On provincial highway projects, deviations from policies contained in Chapter 2 of the RDM shall be justified and documented in the applicable design report(s) for the project.

Desirable values are provided for various features within the roadside environment in the RDM, which should be used for design of new highways and expansion (widening) of existing provincial highways. For major capital rehabilitation or major capital reconstruction of existing highways, desirable values should be considered and explicitly evaluated during design to select cost beneficial treatments within the roadside environment that can be achieved with available funding and other constraints. In addition, as design guidelines, standards and best practices continue to evolve over time, existing highways that were originally constructed according to previous design policies, guidelines and standards, and have acceptable operational and collision histories, should not require reconfiguration or improvements based on desirable values in the RDM. This is further described in Chapter 2.

Designers should achieve a balance between competing objectives and constraints when determining how the roadside environment will be configured. In some cases, engineering judgement is required to assess trade-offs. The choices made to achieve this balance will be influenced by the:

- Functional classification;
- Design speed;
- Operating speed;
- Posted speed;
- Traffic volumes and composition;
- Drainage considerations;
- Pavement design considerations;
- Right-of-way (ROW) constraints (such as property limits, environmental)
- Other ROW user expectations (such as utility companies);
- Access requirements (such as entrances);
- Constructability considerations;
- Maintenance considerations;
- Funding considerations; and
- Other constraints (such as social, political, technological).

Common highway design objectives include:

- Maximizing road user throughput (the number of road users served for a given time period);
- Maximizing road user safety;
- Ensuring an appropriate level of access (Corridor Management Policies and Regulations);
- Minimizing impacts on the natural and socio-economic environments; and
- Minimizing the overall life cycle cost of the facility.

The RDM does not address:

- Drainage design;
- Geotechnical design;
- Maintenance;
- Property management and acquisition;
- Property access;
- Signage (other than sign-supports);
- Utilities (other than poles and boxes); and
- Shared use of ROW (Active Transportation Paths, Recreational Trails, etc.)

1.1 Key Terms Used in Manual

Roadside design, like other areas of highway design, uses many unique terms to define specific physical or operational aspects of the highway or the design process. While the Glossary presents many definitions, it is important for the designer to understand the following key terms:

Area of Concern: An obstacle or area within the roadside environment and within the desirable clear zone that has a higher severity index than a barrier system.

Barrier System: A system which provides a physical limitation through which an errant vehicle would not normally penetrate or vault over. It is intended to contain or redirect an errant design vehicle of a particular size range, at a given speed and angle of impact.

Clear Zone (CZ): The unobstructed, traversable area provided beyond the edge of the travelled way available for use by errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes. The clear zone also includes recoverable slopes, and non-recoverable slopes with a clear run-out area. The selected clear zone width for a project is dependent upon traffic volumes and design speed, and roadside geometry.

Crash Cushion: An energy attenuating system which provides a physical limitation through which an errant vehicle would not normally penetrate. It is intended to contain or redirect or stop an errant design vehicle of a particular size range, at a given speed and angle of impact.

Desirable Value: The value at the top of a range of values in a design standard, or the discreet value when a range is not given in a design standard.

Dynamic Deflection: The maximum distance that the barrier system is expected to deflect laterally under a specified design impact, measured from the traffic face of the system.

Energy Attenuator: Has the same meaning as crash cushion.

Foreslope: A slope parallel to the roadway in a cut (frontslope) or fill (sideslope) section, between the edge of shoulder rounding and bottom of slope. It includes earth or rock, and granular base and sub-base.

Guide Rail: Has the same meaning as barrier system.

Highway: The entire right-of-way comprising of a common or public thoroughfare, including a highway, road, street, bridge, and any incidental thereto.

High Speed Roadways: Roadways with posted speeds of 70 km/h or higher.

Minimum Value: The value at the bottom of a range of values in a design standard.

Obstacle: Any non-breakaway and non-traversable feature within the roadside environment greater than 100mm in height that can increase the potential for personal injury and vehicle damage when struck by an errant vehicle leaving the roadway.

Right-of-Way (ROW): The area of land acquired for or designated to the provision of a highway.

Road: Has the same meaning as Highway.

Roadside Environment: The portion of the ROW beyond the roadway, including medians, not designed for vehicular use. The roadside environment may include a variety of surfaces, slopes, obstacles, and natural features (such as water bodies, vegetation, etc).

Roadway: The portion of the highway, including shoulders, designed for vehicular use.

Severity Index: A number from zero to ten used to categorize the potential severity of an encroachment or impact by an errant vehicle for a range of design speeds over a variety of surfaces and slopes, fixed objects and natural features within the roadside environment. The number is used for evaluating alternative safety treatments.

Shall: A mandatory obligation.

Should: A recommendation that is not a mandatory obligation

Terminal: A crashworthy end treatment or crashworthy anchor used at the end of a barrier system.

Working Width: Distance between the traffic face of a barrier system before a vehicular impact during a specified crash test, and the maximum lateral distance position of any major part of the system or vehicle after impact.

1.2 The Importance of Roadside Design

Collisions that occur within the roadside environment typically involve a vehicle departing the roadway and subsequently impacting an obstacle, or encountering a situation or feature that result in the rollover of the vehicle. These are referred to as run-off-the-road (RoR) collisions.

The 2011 AASHTO Roadside Design Guide indicates that in the United States "about thirty percent, or almost one in every three fatalities, are the result of a single vehicle run-off-the-road crash". According to the Insurance Institute for Highway Safety and Highway Loss Data Institute, in the United States "20 percent of motor vehicle crash deaths result from a vehicle leaving the roadway and hitting a fixed object alongside the road. Trees, utility poles, and traffic barriers are the most common objects struck. Almost half of the deaths in fixed object crashes occur at night. Alcohol is a frequent contributing factor. Motorists also run off the road because of excessive speeds, falling asleep, inattention or poor visibility. Efforts to reduce these driver errors are only somewhat effective, so it's important to remove fixed objects or avoid putting them along roads in the first place if feasible, especially on roads where vehicles are more likely to leave the pavement. Less preferred options include using breakaway objects, shielding objects and increasing the visibility of objects."

The Ontario Road Safety Annual Report (ORSAR) published by MTO states that in 2019 there were 221,793 reportable collisions on all roads across the province. These reportable collisions for all roads in 2019 consisted of 545 fatal collisions, resulting in 584 persons killed, and there were 33,602 personal injury collisions and 187,646 property damage collisions. For provincial highways, the reportable collisions in 2019 consisted of 142 fatal collisions, 5,771 personal injury collisions, and 37,421 property damage collisions. ORSAR is updated and published annually by the ministry and is available on the ministry's web site at: http://www.mto.gov.on.ca/english/publications/ontario-road-safety-annual-report.shtml

Although ORSAR does not specify how many of the collisions occurred within the roadside environment, it is likely that Ontario's experience with RoR collisions is similar to that experienced in the United States. The Insurance Institute for Highway Safety and Highway Loss Data Institute published a pie chart showing percentage distribution of fatal crashes by obstacle struck in the United States for the year 2015, which is reproduced in Figure 1-2.

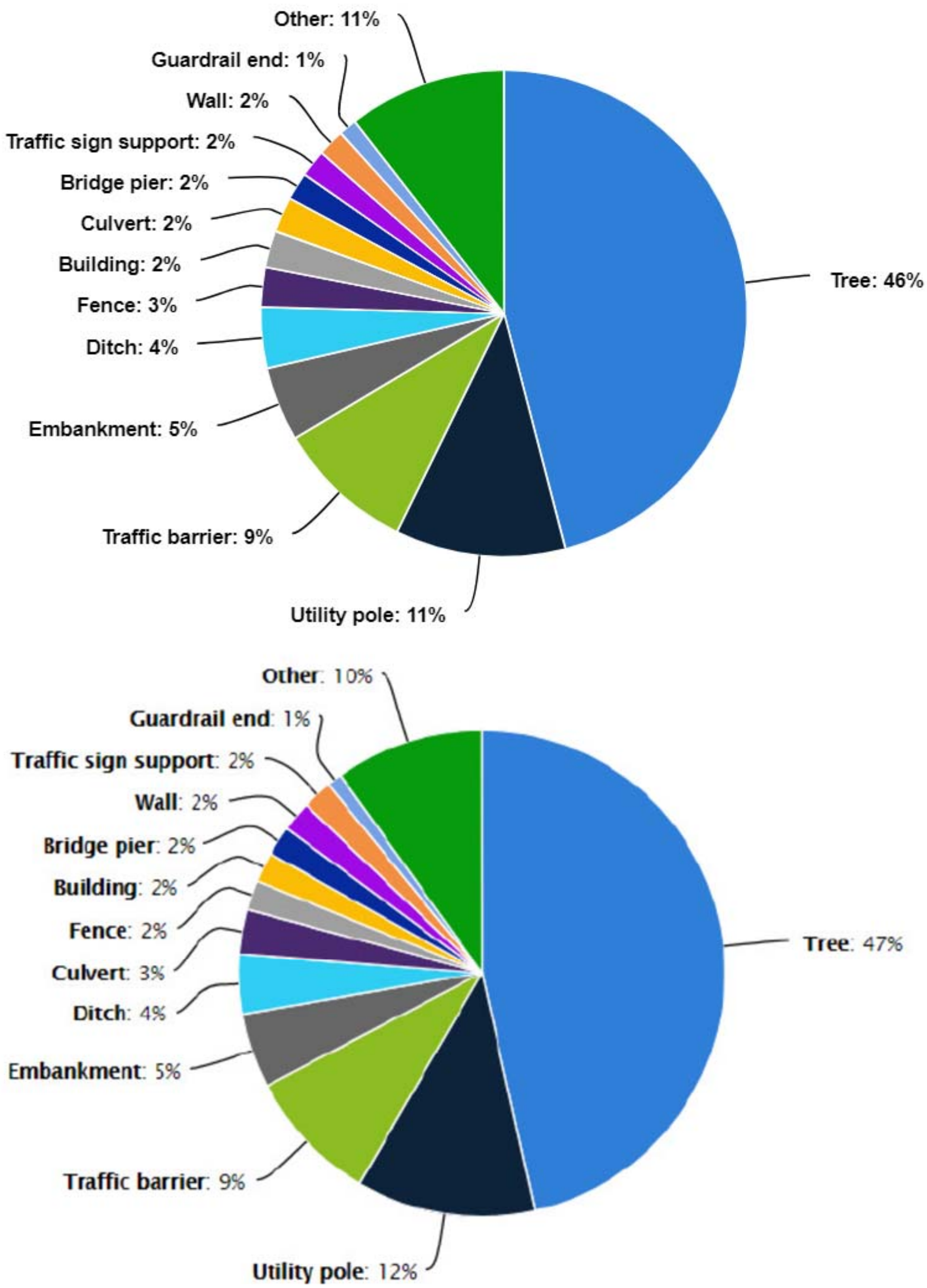


Figure 1-2 – Percent Distribution of Fatal Crashes by Obstacle Struck in US, 2020 *

* Pie Chart from Insurance Institute for Highway Safety and Highway Loss Data Institute, Washington, DC, 2020: http://www.iihs.org/iihs/topics/t/roadway-and-environment/fatalityfacts/fixed-object-crashes

1.3 Historical Perspective

The emphasis on roadside safety design emerged in North America during the 1960s. Designers came to realize that some motorists, regardless of the improvements made, may run off the roadway. It also became clear that serious collisions within the roadside environment could be reduced if a traversable recovery area was provided.

Many studies have been done to gain a better understanding of the path and stability of errant vehicles when they encroach onto the roadside environment. The vehicle behaviour depends largely on the nature of the roadside, vehicle speed, the circumstances that caused the roadside encroachment, and the characteristics of the vehicle. On traversable roadside terrain, the driver may be able to regain some control of the vehicle after the vehicle has left the travelled way, and either bring the vehicle to a stop or return to the roadway.

Test track experience and full scale testing at the GM Proving Grounds in the 1950s established a basic understanding of encroachment distance relationship and geometry of the roadside. The standard cross-section implemented at the GM Proving Ground test tracks in 1958 included 3 m (10 foot) shoulders, 6H:1V or flatter foreslopes and backslopes, and a roadside clear of obstacles for a minimum distance of 30m (100 feet) on each side of the travelled way. Field studies conducted in the mid-1960s and 1970s enhanced the understanding of the encroachment distance relationship for RoR collisions. This encroachment distance relationship is illustrated in Figure 1-3. While this encroachment relationship was first established almost 60 years ago, it is still relevant today.

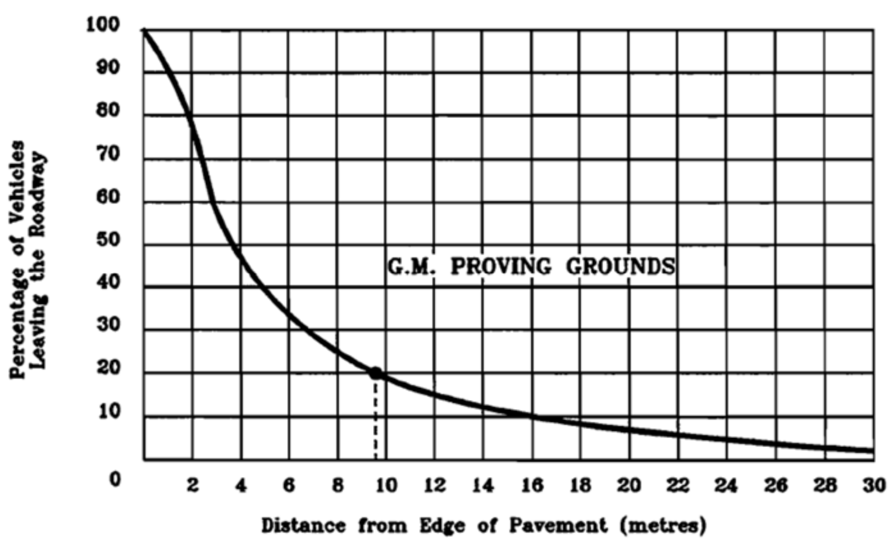


Figure 1-3 – GM Proving Ground Encroachment Relationship

As an example, Figure 1-3 indicates that on high speed roadways, a traversable, flat, obstacle free area adjacent to the travelled way results in about 80% of errant vehicles departing the travelled way to recover or stop before encroaching more than 9.1 m (30 feet) beyond the edge of travelled way. Conversely, about 20% of errant vehicles leaving the travelled way are expected to encroach more than 9.1 m (30 feet) from the travelled way. Where this area slopes downward away from the roadway, out of control vehicles will likely encroach further away from the travelled way. Conversely where this area slopes upward away from the roadway, encroachment distances should be less.

Roadside safety design treatments have also evolved over time. Roadway embankments were initially constructed using similar principles to those used for construction of railway embankments. Steep foreslopes were used to minimize the amount of materials and grading required. The steepness of the slope was typically governed by the loading requirements to support the roadway and to limit erosion. Construction through rock necessitated almost vertical walls due to cost. Early construction practices would usually result in very rough or jagged rock faces. It is now understood that providing flatter wider areas adjacent to the roadway can reduce the lateral extent and severity of encroachments within the roadside environment.

1.4 Contents of the Manual

The RDM provides cost beneficial design guidelines, standards and policies for design of the roadside environment and features on provincial highway projects.

Chapter 1 provides an introduction, historical perspective, and the general philosophy and principles of design of the roadside environment. Key terms from the glossary that are used extensively throughout the RDM are also defined.

Chapter 2 provides the ministry's policies, standards, and guidelines for design of the roadside environment on provincial highway projects.

Chapter 3 provides design processes for selection of appropriate design treatments within the roadside environment on provincial highway projects. A set of decision charts is included to guide the designer through the design process toward the selection of the most appropriate and cost beneficial design treatment for the situation and feature under consideration.

Chapter 4 provides the performance characteristics and design details for new roadside safety hardware to be used on provincial highway projects including barrier systems, terminals, crash cushions and small signs.

Chapter 5 provides the performance characteristics and design details for roadside safety hardware to be used within work zones on provincial highway projects including temporary barrier systems and temporary crash cushions.

Appendix A provides the MTO Severity Index Tables for many roadside features for a range of design speeds from 50 km/h to 120 km/h including various foreslope and backslope configurations, drainage ditches, and various obstacles such as trees, poles, piers, barrier systems, terminals, and culvert treatments. These tables are to be used for explicit benefit cost evaluations of alternative safety treatments during design of provincial highway projects.

Appendix B provides a glossary of terms common to the RDM and the MTO Design Supplement for the TAC Geometric Design Guide for Canadian Roads, June 2017.

1.5 Safety Sensitive Design

Significant improvements in safety are not automatic by-products of highway projects. In some cases, collision data may not be available or collision experience may not highlight the need to make a safety improvement, or to take advantage of a potential opportunity to improve safety. The designer should deliberately and systematically consider potential opportunities within each project to apply sound safety and traffic engineering principles.

At the beginning of the project the designer should assess the existing physical and operational conditions affecting safety by using collision data, site inspections and existing design and traffic characteristics. Consideration should be given to locations where the consequences of a collision may be severe.

Safe System Approach:

The Safe System Approach is designed with the human being at its centre, not only taking human fallibility and vulnerability into account, but accepting that even the most conscientious people make mistakes. The goal of the Safe System Approach is to ensure that these mistakes do not result in a collision; or, if a collision does occur, its effects are sufficiently mitigated so as to not cause death or life-changing injuries. It requires that all those involved directly and indirectly in the design, operation, maintenance and use of the system understand how various components of the system interact and strive to minimize human error or mitigate its consequences. In a Safe System Approach, one of the central components is safe roads. Safe roads are designed, operated and maintained to reduce the risk of collisions occurring and the severity of an injury, should they occur. While all road users must always try to interact with each other and the facility safely, the Safe System Approach emphasizes that the transportation system must be designed to accommodate human vulnerability and error. The safe system approach has been adopted and developed by several organizations such as TAC and FHWA and is increasingly informing highway engineering practises within MTO.

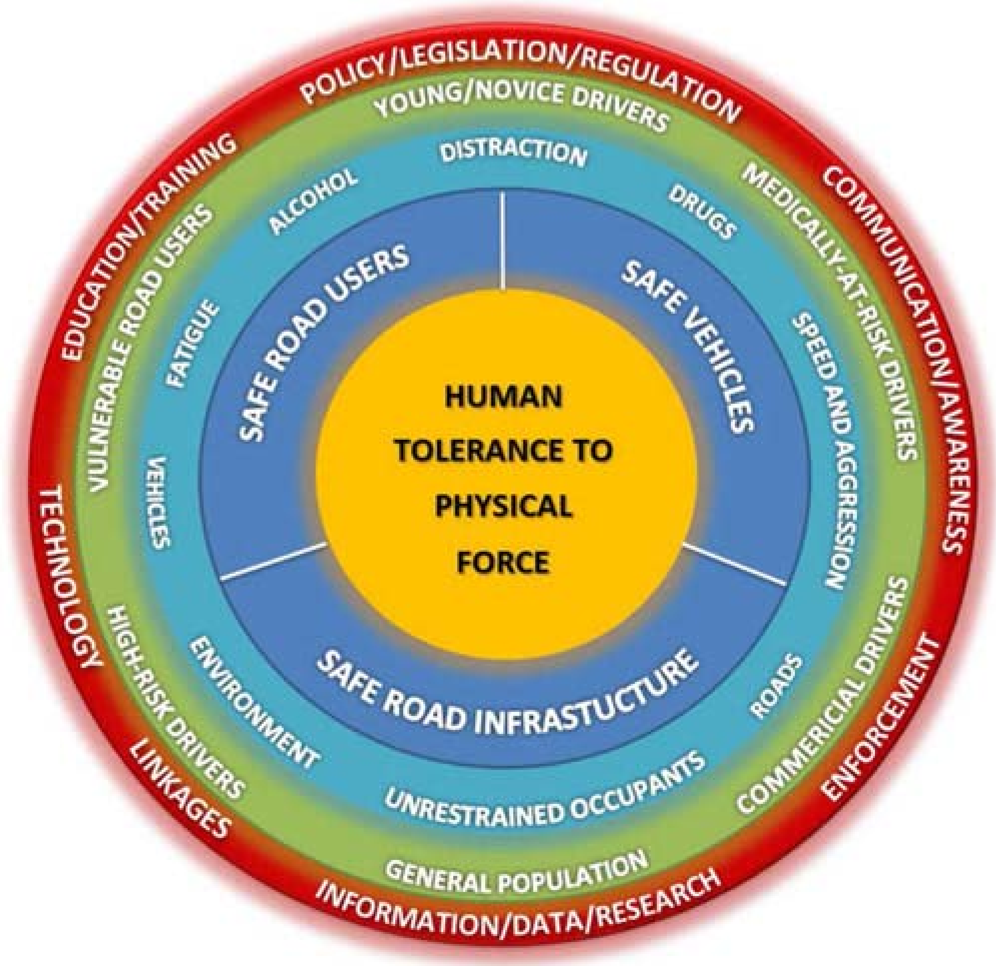


Figure 1-4 – Canadian Council of Motor Transport Administrators adapted from the 2009 WHO report on the Global Status on Road Safety

Adopting a Safe System approach necessarily means adopting a culture of safety consciousness, putting safety first and following Safe Systems principles in each of the engineering decisions made during design. In relationship to this manual, the central component of a Safe Systems Approach is accommodating human tolerance to physical force by reducing impact forces. This can be accomplished through reducing the angle and speed of impacts and improving roadside crashworthiness through a forgiving roadside with clear zones, breakaway hazards where possible and barriers to current standards where necessary. Designers must consider that vehicles will leave the roadway and interact with roadside hazards, then consider the appropriate level of protection based on the expected mix of users. These decisions must also be made considering the context of equity for all users recognizing that vulnerable users will be present along with a mix of transportation modes on our highways.

1.6 Risk Mitigation and Treatment

It is recognized that it is not practical or cost beneficial to incorporate all possible safety improvements into every major capital works project on the provincial highway system due to physical, environmental, and/or funding priorities and constraints. However, the designer is encouraged to be proactive in improving safety where practical and cost beneficial. The intent of providing a clear zone adjacent to the travelled way is to minimize the probability of collisions with obstacles in the roadside environment by errant vehicles departing the roadway.

Ideally, the designer should strive towards providing the widest clear zone that can be reasonably afforded, fully considering physical, environmental, and funding constraints. However, this is not always practical. In such circumstances, the roadside mitigation treatments listed below in order of preference, should be considered and evaluated to determine the appropriate cost beneficial design alternative treatment to reduce the probability and/or severity of collisions with a roadside obstacle or area of concern.

Roadside Mitigation Treatment in Order of Preference:

1. Remove the obstacle;
2. Relocate the obstacle to a location to reduce the probability of it being impacted
3. Redesign the obstacle so that it can be safely traversed;
4. Reduce the impact severity of the obstacle by using an appropriate breakaway design;
5. Shield the obstacle with a barrier system or crash cushion;
6. Delineate the obstacle, if the above mitigation measures are not appropriate; and
7. Reduce the posted speed.

As noted above, the most preferred treatment is to remove or relocate the obstacle, unless other considerations, such as cost and environmental impact, make its removal or relocation impractical. For example, trees pose a hazard to errant vehicles and should be removed from the clear zone. However, there may be situations where the removal of trees may cause adverse effects to the environment, or they may have heritage value. In these cases, the reason to justify keeping them should be documented in the project files (Design Criteria).

If the removal or relocation of an obstacle is not practical, the obstacle should be shielded (as in the trees example), or where possible, the severity (e.g. severity index) of the obstacle may be reduced by other means, such as making it traversable, using an appropriate breakaway design, flattening slopes, or utilizing traversable (safety) culvert end treatments. These treatments are preferable to shielding them with a barrier system or crash cushion.

Although barrier systems and crash cushions are designed and crash tested to minimize the severity of injuries to occupants in passenger vehicles from collisions with roadside obstacles dependent on the type of impact, significant vehicle damage can occur including injury to occupants under certain conditions. Once a barrier system or crash cushion comes into use, the crash is already in progress. The purpose of a barrier system or crash cushion is therefore not to prevent a crash, but rather to minimize the severity of the crash.

1.7 Relationship to Other Design Documents

The Roadside Design Manual should be used and read in conjunction with other guidelines, manuals, standards and codes such as:

- Canadian Highway Bridge Design Code (CHBDC);
- MTO Bikeway Design Manual
- MTO Contract Design Estimating and Documentation Manual (CDED);
- MTO Contract Preparation System (CPS);
- MTO Drainage Design Standards;
- MTO Drawings (MTOD);
- MTO Design Standards Section Drawings (DSSD);
- MTO Electrical Engineering Manual;
- MTO Design Supplement to the TAC Geometric Design Guide for Canadian Roads;
- MTO Maintenance Manual;
- MTO Provincial Engineering Memorandums;
- MTO Sign Support Manual;
- MTO Standard Special Provisions;
- Ontario Provincial Standard Drawings (OPSD);
- Ontario Provincial Standard Specifications (OPSS),
- Ontario Traffic Manuals (OTM), and;
- TAC Geometric Design Guide for Canadian Roads (as referenced in MTO Geometric Design Supplement to the TAC Geometric Design Guide for Canadian Roads).

2. Roadside Design Policies, Standards and Guidelines

2.1 Introduction

Policies, standards and guidelines used for the design of the roadside environment on provincial highway projects are provided in this chapter. Deviations from policies and standards in Chapter 2 should be justified and documented in the Design Criteria. Deviations may also be documented as applicable in other design report(s), including but not limited to the Project Scope and Cost Report (SCR), Preliminary Design Report (PDR), Project Assessment Report (PAR), or Corridor Investment Plan (CIP).

Policies are clearly stated in bold text under the heading “Policy”. Each policy defines when they are applicable on a provincial highway project. Standards are referenced in each policy as required. Design guidance is provided in the preceding text before each policy, and additional design guidance and details are provided in Chapters 3, 4 and 5.

Highway design and roadside safety practices have evolved over time as research projects and updated roadside safety features, practices, and hardware have been developed, tested, implemented and evaluated. As such, an existing highway can exhibit a broad range of design treatments and roadside safety hardware over the length of a corridor, reflecting the era of initial construction, reconstruction or rehabilitation.

The roadside environment, including medians, on Major Capital Expansion projects as defined in Table 2-1 should be designed according to the applicable policies and standards in Chapter 2 unless otherwise justified and documented within the applicable design report(s).

On Major Capital Rehabilitation projects and Major Capital Reconstruction projects as defined in Table 2-1, explicit benefit/cost evaluations should be used to determine whether applicable policies and standards in Chapter 2 including desirable roadside safety or median improvements are cost beneficial for inclusion with the project, or whether such improvements should be deferred to a future rehabilitation, reconstruction or expansion project. Decisions should be justified and documented within the applicable design report(s).

Roadside design decisions should be consistent with the applicable Corridor Investment Plan and Project Scope and Cost Report.

Category of work for Capitalization Purposes	Category of work for Programming Purposes	Characteristics of Work for Design Purposes
Operating/Maintenance (expensed)	Emergency Maintenance Work	• Work that requires immediate repairs – unforeseen or unplanned hazards.
	Maintenance	• Work that must be done on a periodic basis to eliminate actual or potential safety hazards. • Work that is identified in the Maintenance Quality Standards.
Minor Capital Work (capitalized)	Holding	• An action taken when an asset does reach the trigger (threshold) value but a full rehabilitation/reconstruction is not undertaken. This work will maintain acceptable levels of functionality or safety and prolongs the life of the asset.
	Preventive	• Work is done before the asset reaches the trigger (threshold) value. Planned strategies that extend the life of the asset or enhance its service potential. • Work undertaken to a small section or component of an asset to be consistent with the overall asset.
Major Capital (capitalized)	Rehabilitation	• Renews the life of an asset. • Activities performed when the trigger value has been achieved, at the end of the anticipated service life. This work restores serviceability and improves an existing asset to a condition of structural or functional adequacy.
	Reconstruction	• Activities may be performed at the end of the anticipated service life, but typically after two or three rehabilitation cycles. Generally the complete or major removal and replacement of an existing asset.
	Expansion	• Capital improvement that improve the asset's performance or capacity either as part of a reconstruction of an existing asset or a green field project.

Table 2-1: Category of Work

2.2 Design Procedures and Roadside Safety Hardware

Roadside design procedures, design treatments, and roadside safety hardware selected for use on provincial highway projects are presented in this manual. However, new procedures and concepts are continually being developed along with new or modified roadside safety hardware. Design, installation, maintenance and repair guides are available from roadside safety hardware manufacturers to provide supplemental detailed information for products used on provincial highway projects.

It is important to ensure that the design processes and roadside safety hardware selections used across the province on provincial highway projects are consistent for similar situations. The application of other procedures, other roadside design treatments, and modifications to roadside safety hardware should be reviewed with the Highway Design Office prior to being used on provincial highway projects.

POLICY: **On Provincial Highway Projects, only roadside design procedures authorized by the Highway Design Office should be used for design of roadside environments**

2.3 Roadside Design

2.3.1 Desirable Clear Zone

It is recognized that some vehicles will run off the road, regardless of the design of the roadway. It is desirable for errant vehicles that have departed the travelled way to have an opportunity to stop or slow down within the roadside before encountering obstacles. This is intended to reduce the number of fatality and injury crashes that can occur within the roadside environment. As described in Section 1.3, test track experience and full scale testing at the GM Proving Grounds in the 1950s established a basic understanding of encroachment distance relationship and geometry of the roadside environment.

A significant number of serious collisions, and the severity of injuries sustained during encroachments onto the roadside environment, can be reduced if a clear zone is provided adjacent to the travelled way. The clear zone selected and provided within the right-of-way to accommodate the path of most errant vehicles should be traversable, and be free of obstacles, such as unyielding landscaping, bridge piers, sign supports, light poles, non-traversable ditches, rigid drainage features, and steep slopes. When obstacles or areas of concern cannot be eliminated, relocated, or made traversable or breakaway within the selected clear zone, barrier systems or crash cushions should be considered and evaluated to determine if they would be a cost effective design treatment to shield the obstacle or area of concern from errant vehicles.

Vehicle impacts with barrier systems, crash cushions and breakaway systems will likely involve vehicle damage and may result in occupant injury, dependent on the physical characteristics of the errant vehicle, and on the angle, speed, and orientation of the errant vehicle at point of impact. The severity of an impact for a vehicle interacting with a barrier system or crash cushion should be less severe than the severity of interacting with the obstacle(s) being shielded. Designers should strive to eliminate the need for barrier systems and crash cushions by providing desirable clear zones wherever practical and cost beneficial. Roadside safety is enhanced by providing a forgiving roadside.

The desirable clear zone values provided in Table 2-2 and the horizontal curve adjustment factors provided in Table 2-3 are modified and based on suggested clear zone distances and adjustment factors from the AASHTO Roadside Design Guide. These distances were based on limited empirical data that was extrapolated to provide values for a wide range of conditions. The values should be considered as approximate and not a precise value to be held as absolute.

POLICY: **On Major Capital Expansion Projects, all obstacles within the desirable clear zone according to Table 2-2 and Table 2-3 that cannot be removed, relocated or made breakaway, should be shielded by a barrier system or crash cushion.**

On Major Capital Reconstruction Projects, all obstacles within the desirable clear Zone according to Table 2-2 and Table 2-3 should be evaluated to determine whether alternative roadside mitigation treatments are practical, cost beneficial, and should be included with the project or deferred to a future rehabilitation, reconstruction or expansion project.

On Capital Rehabilitation Projects, when obstacles are identified and prioritized as areas of concern through on-going operational and collision reviews, alternative mitigation treatments should be evaluated to determine whether the treatments are practical, cost beneficial, and should be included with the project or deferred to a future rehabilitation, reconstruction or expansion project.

Design decisions should be documented in the project's Design Criteria.

Design Speed Km/h	AADT	Negative Foreslope (Fill)			10H:1V or flatter	Positive Foreslope		
		3H:1V	4H:1V to 5H:1V	6H:1V or flatter		6H:1V or flatter	5H:1V to 4H:1V	3H:1V
≥ 110	**≥ 6,000**	Note 1	14	10.5	9.5	9	9	7.5
	≥ 1,500	Note 1	13	10	9	8.5	7.5	6
	≥ 750	Note 1	11	8	7	6.5	6	5
	< 750	Note 1	8	6	5.5	5	5	3.5
100	**≥ 6,000**	Note 1	13.5	10	9	8.5	8	6.5
	≥ 1,500	Note 1	12	9	8.5	8	6.5	5.5
	≥ 750	Note 1	10	7.5	7	6.5	5.5	4.5
	< 750	Note 1	7.5	5.5	5.5	5	4.5	3.5
90	**≥ 6,000**	Note 1	10	7.5	7.5	7.5	6.5	5.5
	≥ 1,500	Note 1	9	6.5	6.5	6.5	5.5	5
	≥ 750	Note 1	7.5	5.5	5.5	5.5	5	3.5
	< 750	Note 1	5.5	4.5	4	3.5	3.5	3
70 to 80	**≥ 6,000**	Note 1	8.5	6.5	6.5	6.5	6	5
	≥ 1,500	Note 1	8	5.5	5.5	5.5	5	4.5
	≥ 750	Note 1	6	5	5	5	4.5	3.5
	< 750	Note 1	4.5	3.5	3.5	3.5	3	3
≤ 60	**≥ 6,000**	Note 1	5.5	5	5	5	5	5
	≥ 1,500	Note 1	5	4.5	4.5	4.5	4.5	4.5
	≥ 750	Note 1	4.5	3.5	3.5	3.5	3.5	3.5
	< 750	Note 1	3	3	3	3	3	3

Note 1: Errant vehicles encroaching onto non-recoverable slopes (parallel foreslopes steeper than 4H:1V) likely will not be able to stop or return to the roadway easily, and typically can be expected to encroach beyond the toe of slope. Fixed objects should not be present in the vicinity of the toe of non-recoverable slopes. Determination of the width of recovery area at the toe of slope should take into consideration right-of-way availability, width of shoulder, environmental constraints, collision history, and slope beyond toe of slope. Desirable width of recovery area at toe of slope when slope beyond toe of slope is relatively flat should be the applicable desirable clear zone value for 10H:1V slope or flatter, minus width of shoulder and half width of rounding, and should not be less than 3m.

Note 2: Positive foreslopes at bridge abutments up to 2H:1V do not require protection.

Table 2-2: Desirable Clear Zone Values

Table modified from AASHTO Roadside Design Guide.

<table>
<tr><th rowspan="2">Radius (m)</th><th colspan="6">Design Speed (km/h)</th></tr>
<tr><th>60</th><th>70</th><th>80</th><th>90</th><th>100</th><th>≥110</th></tr>
<tr><td>900</td><td rowspan="4">1.1</td><td rowspan="2">1.1</td><td>1.1</td><td rowspan="3">1.2</td><td rowspan="2">1.2</td><td>1.2</td></tr>
<tr><td>700</td><td rowspan="3">1.2</td><td>1.3</td></tr>
<tr><td>600</td><td rowspan="4">1.2</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td></tr>
<tr><td>500</td><td rowspan="3">1.3</td></tr>
<tr><td>450</td><td rowspan="4">1.2</td><td rowspan="3">1.3</td><td rowspan="2">1.4</td><td>1.5</td></tr>
<tr><td>400</td><td rowspan="7"></td></tr>
<tr><td>350</td><td>1.4</td><td rowspan="2">1.5</td></tr>
<tr><td>300</td><td rowspan="2">1.3</td><td rowspan="2">1.4</td><td rowspan="2">1.5</td></tr>
<tr><td>250</td><td rowspan="2">1.3</td><td rowspan="4"></td></tr>
<tr><td>200</td><td>1.4</td><td>1.5</td><td rowspan="3"></td></tr>
<tr><td>150</td><td>1.4</td><td>1.5</td><td rowspan="2"></td></tr>
<tr><td>100</td><td>1.5</td><td></td></tr>
</table>

Note: Horizontal Curve Adjustment Factors should only be applied to the outside of horizontal curves with radii of 900 m or less.

Table 2-3: Horizontal Curve Adjustment Factors

Table based on AASHTO Roadside Design Guide

2.3.2 Slopes

Parallel slopes along a roadway perform two essential functions within the roadside environment. Foreslopes (includes frontslopes and sideslopes in cut and fill sections respectively) provide structural support for the roadway, and in conjunction with backslopes (in cut) provide a transition between the roadway and original ground. Slopes are typically described by the ratio of horizontal to vertical change in slope (e.g., a 4H:1V is a slope that changes 1 m vertically for every 4 m measured horizontally).

The structural support function of the foreslope can often be achieved with slopes as steep as 1H:1V or even vertical slopes, dependent on the material used to construct the slope. However, the transitional function of the foreslope influences errant vehicle stability, and hence safety. Flatter slopes on high speed roadways are desirable because they result in less abrupt transitions between adjacent surfaces, decrease the risk of vehicle roll-over and tend to reduce the lateral distance away from the road that an errant vehicle will travel.

On freeways and high speed arterial roads with reasonably wide roadsides, foreslopes and backslopes should be designed to provide a reasonable opportunity for recovery of errant vehicles. Foreslopes of 6H:1V or flatter can be negotiated by a vehicle with a reasonable chance of recovery and should therefore be provided where practical and cost beneficial. Foreslopes of 4H:1V or flatter are recoverable where height is moderate. Foreslopes of 3H:1V or flatter and steeper than 4H:1V are traversable where the height is moderate. Foreslopes steeper than 3H:1V are considered critical as there is a higher probability of errant vehicles overturning, and may justify shielding with a barrier dependent on height, length, and uniformity of the critical slope, which should be evaluated using MTO’s Roadside Evaluation Manual and MTO’s Roadside.xlsx program.

Further flattening of slopes may be considered dependent on availability of material and property. Flat and well rounded slopes simplify the establishment of vegetative ground cover and its subsequent maintenance. Slopes 3H:1V or flatter are desirable for maintenance reasons, and usually vegetative ground cover can be readily established on slopes as steep as 2H:1V.

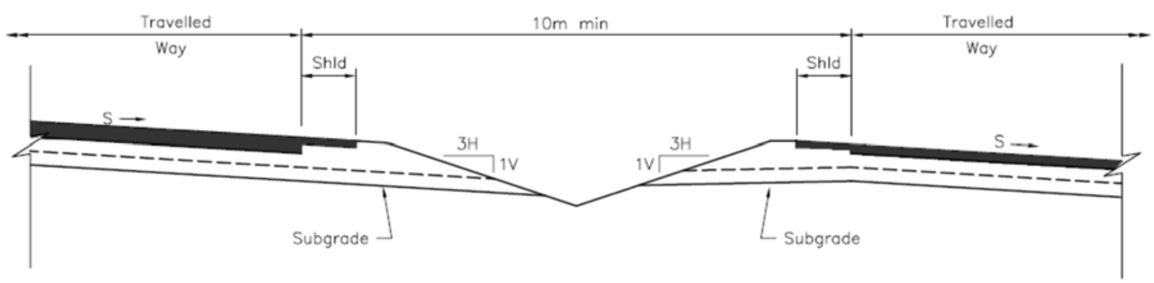
Figure 2-1 provides desirable section for medians separating low speed interchange ramps.

POLICY: On Major Capital Expansion Projects, desirable foreslopes and backslopes should be according to Tables 2-4 through 2-7. At locations where barrier systems are required, foreslopes and backslopes may be steeper dependent on the functional foundation requirements of the selected barrier system.

On Major Capital Reconstruction Projects, desirable foreslopes and backslopes should be according to Tables 2-4 through 2-7 when cost beneficial.

On Major Capital Expansion and Reconstruction Projects, medians separating low speed interchange ramps should be minimum 10 m wide with 3H:1V foreslopes and backslopes. At locations where barrier systems are required, foreslopes and backslopes may be steeper dependent on the functional foundation requirements of the selected barrier system.

Appendix A provides severity indices for various surfaces, foreslopes, and backslope configurations for a range of design speeds.



Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-1: Desirable Grading Section for Medians Separating Low-Speed Interchange Ramps

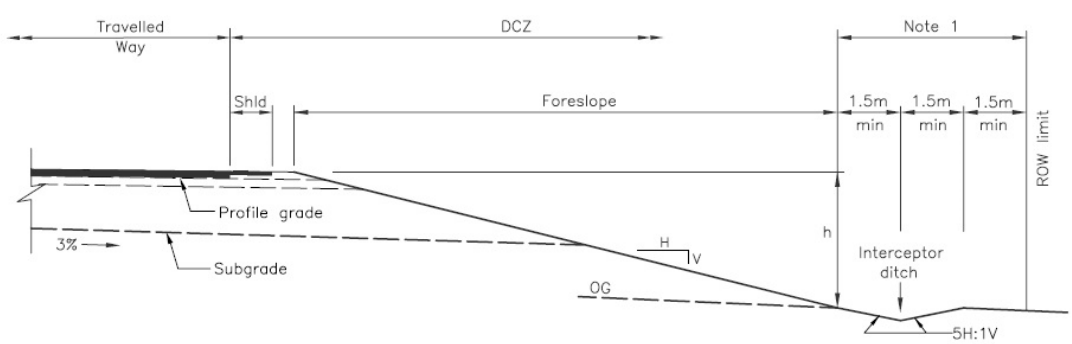


Figure 2-2: Earth/Shale Fill Sections
To be used with Table 2-4

Functional Classification	Design Speed (km/h)	Height: h (m)	Design Year AADT	Foreslope Ratio
Freeway	All	h ≤ 3	All	6H:1V
		3 < h ≤ 4.5	All	5H:1V
		4.5 < h ≤ 6	All	4H:1V
		h > 6	All	2H:1V Note 1
Interchange Ramp	≥ 100	h ≤ 3	All	6H:1V
		3 < h ≤ 6	All	4H:1V
		h > 6	All	2H:1V Note 1
	70 to 100	h ≤ 6	All	4H:1V
		h > 6	All	2H:1V Note 2
	< 70	h ≤ 6	All	3H:1V
		h > 6	All	2H:1V Note 2
Arterial	≥ 70	h ≤ 2	All	6H:1V
		2 < h ≤ 4	> 20,000	6H:1V
			≤ 20,000	4H:1V
		4 < h ≤ 5	All	4H:1V
		5 < h ≤ 6	> 20,000	4H:1V
			≤ 20,000	2H:1V Note 2
		h > 6	All	2H:1V Note 2
	< 70	h ≤ 2	All	4H:1V
		2 < h ≤ 4	All	3H:1V
		h > 4	All	2H:1V Note 2
Collector and Local	≥ 70	h ≤ 2	All	4H:1V
		2 < h ≤ 6	All	3H:1V
		h > 6	All	2H:1V Note 2
	< 70	h ≤ 6	All	3H:1V
		h > 6	All	2H:1V Note 2

Note 1: Roadside barrier recommended with 4H:1V foreslope above subgrade.

Note 2: Roadside barrier recommended with 3H:1V foreslope above subgrade.

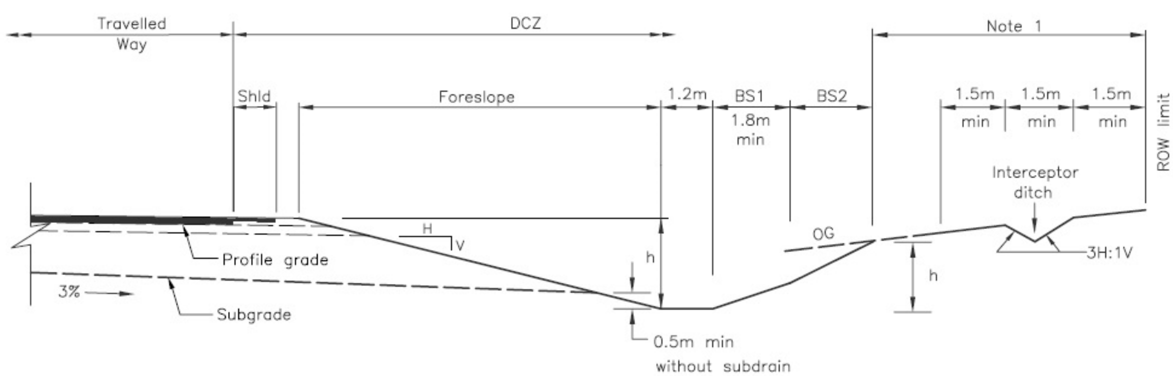
Table 2-4: Desirable Earth and Shale Fill Foreslopes

To be used with Figure 2-2

Functional Classification	**Design Speed (km/h)**	**Height: h (m)**	**Design AADT**	**Foreslope Ratio**	**Backslope Ratio**	
					BS1	**BS2**
Freeway	All	h ≤ 3	All	6H:1V	3H:1V	2H:1V
		h > 3	All	4H:1V	4H:1V	2H:1V
Interchange Ramp	≥ 100	h ≤ 2	All	6H:1V	3H:1V	2H:1V
		h > 2	All	4H:1V	4H:1V	2H:1V
	70 to 100	h ≤ 2	All	6H:1V	3H:1V	2H:1V
		h > 2	All	4H:1V	4H:1V	2H:1V
	<70	h ≤ 2	All	3H:1V	3H:1V	2H:1V
		h > 2	All	3H:1V	2H:1V	2H:1V
Arterial	≥70	h ≤ 2	All	6H:1V	3H:1V	2H:1V
		h > 2	All	4H:1V	4H:1V	2H:1V
	<70	h ≤ 3	All	3H:1V	3H:1V	2H:1V
		h > 3	All	3H:1V	2H:1V	2H:1V
Collector and Local	≥70	h ≤ 1	All	4H:1V	4H:1V	2H:1V
		h > 1	All	3H:1V	3H:1V	2H:1V
	<70	All	All	3H:1V	2H:1V	2H:1V

Note 1: Dependent on local soil conditions, Backslope-2 may need to be flatter.

Table 2-5: Desirable Earth and Shale Cut Slopes
To be used with Figure 2-3



Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-3: Earth/Shale Cut Sections
To be used with Table 2-5

Functional Classification	Design Speed (km/h)	Height: h (m)	Design AADT	Foreslope Ratio
Freeway	All	h ≤ 2	All	6H:1V
		2 > h ≤ 4	> 15,000	6H:1V
			≤ 15,000	4H:1V
		h > 4	All	1.25H:1V Note 1
Interchange Ramp	≥ 100	h ≤ 3	All	6H:1V
		3 < h ≤ 6	All	4H:1V
		h > 6	All	1.25H:1V Note 1
	70 to 100	h ≤ 6	All	4H:1V
		h > 6	All	1.25H:1V Note 1
	< 70	h ≤ 6	All	3H:1V
		h > 6	All	1.25H:1V Note 2
Arterial	≥ 70	h ≤ 2	All	6H:1V
		2 < h ≤ 4	> 25,000	6H:1V
			≤ 25,000	4H:1V
		4 < h ≤ 5	All	4H:1V
		5 < h ≤ 6	> 25,000	4H:1V
			≤ 25,000	1.25H:1V Note 1
		h > 6	All	1.25H:1V Note 1
	< 70	h ≤ 2	All	4H:1V
		2 < h ≤ 4	All	3H:1V
		h > 4	All	1.25H:1V Note 2
Collector and Local	All	h ≤ 2	All	4H:1V
		2 < h ≤ 3	> 1000	4H:1V
			≤ 1000	3H:1V
		h > 3	All	1.25H:1V Note 2

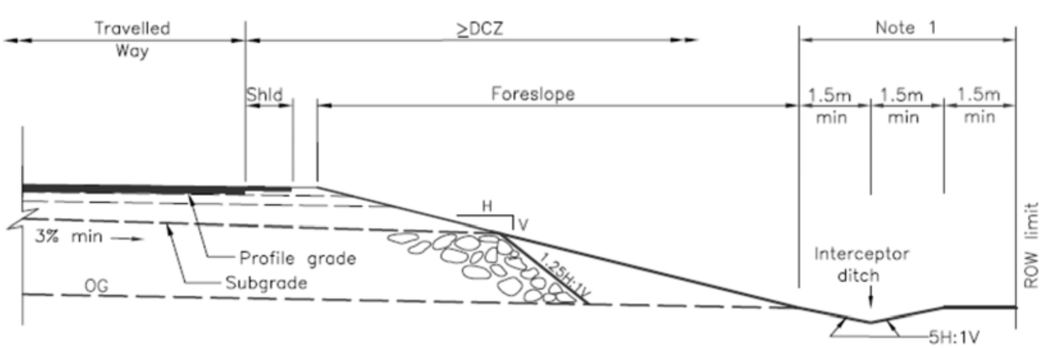
Note 1: Roadside barrier recommended with 4H:1V foreslope above subgrade.
Note 2: Roadside barrier recommended with 3H:1V foreslope above subgrade.

Table 2-6: Desirable Rock Fill Foreslopes
To be used with Figure 2-4

Functional Classification	Design Speed (km/h)	Height: h (m)	Design AADT	Foreslope Ratio	Backslope Ratio	
					BS1	BS2 Note 1
Freeway	All	h ≤ 4	All	6H:1V	3H:1V	2H:1V
		h > 4	All	6H:1V	0.25H:1V	NA
Interchange Ramp	≥ 100	h ≤ 4	All	6H:1V	3H:1V	2H:1V
		h > 4	All	6H:1V	0.25H:1V	NA
	70 to 100	h ≤ 3	All	4H:1V	4H:1V	2H:1V
		h > 3	All	4H:1V	0.25H:1V	NA
	< 70	h ≤ 2	All	4H:1V	4H:1V	2H:1V
		h > 2	All	3H:1V	0.25H:1V	NA
Arterial	≥ 70	h ≤ 3	All	6H:1V	3H:1V	2H:1V
		h > 3	All	6H:1V	0.25H:1V	NA
	< 70	h ≤ 3	All	4H:1V	3H:1V	2H:1V
		h > 3	All	4H:1V	0.25H:1V	NA
Collector And Local	All	h ≤ 2	All	4H:1V	4H:1V	2H:1V
		h > 2	All	4H:1V	0.25H:1V	NA

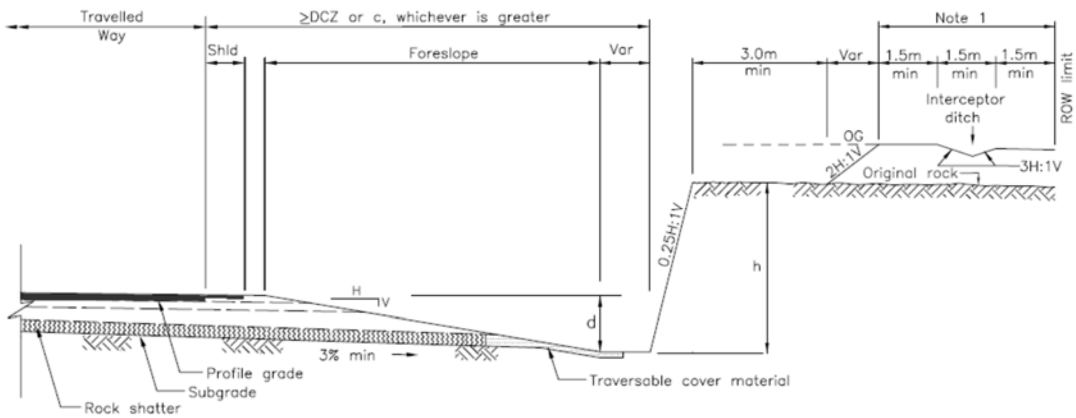
Note 1: Dependent on local conditions including location of DCZ and depth of ditch for rock fall, 2H:1V Backslope-2 may be as steep as 0.25H:1V.

Table 2-7: Desirable Rock Cut Foreslopes and Backslopes
To be used with Figure 2-5 and 2-6



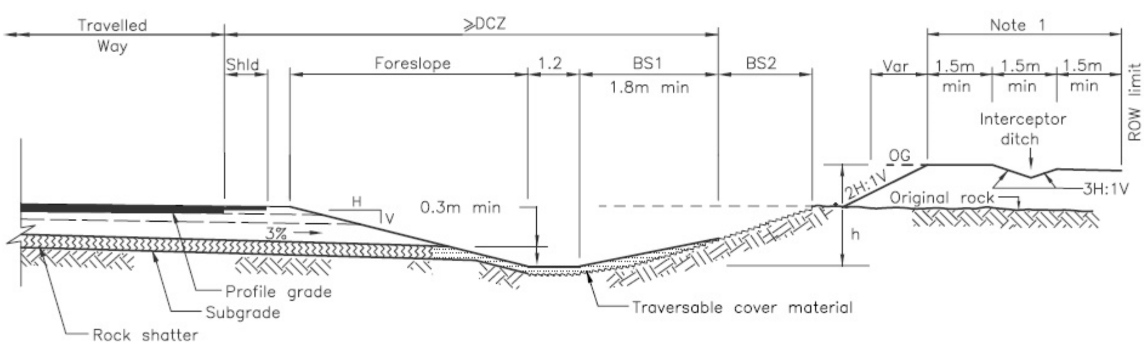
Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-4: Rock Fill Sections
To be used with Table 2-6



Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-5: Rock Cut Sections: 0.25H:1V Rock Face
To be used with Table 2-7



Note 1: Distance should be 1.5 m minimum when ditch not required.

Figure 2-6: Rock Cut Sections: Buried Backslope
To be used with Table 2-7

2.3.3 Shoulder Rounding

Shoulder rounding is the transition between the shoulder cross-fall and the foreslope. It provides additional material beyond the edge of shoulder to provide lateral support of the shoulder and to provide a relatively smooth transition to the foreslope for an errant vehicle departing the roadway. Rounded slopes reduce the probability of an errant vehicle at sharper encroachment angles from becoming airborne, therefore potentially reducing the severity of the encroachment and affording the driver more opportunity for control of the vehicle with tires still in contact with the ground.

Shoulder rounding is also required to provide lateral stability for barrier systems that use posts to support cables or beams, and provide lateral stability for embedded roadside concrete barrier systems.

At least half of the rounding width may also be used by drivers during an emergency stop on the shoulder to increase offset to moving traffic in the adjacent travel lanes.

Providing desirable rounding widths on Major expansion and Reconstruction Projects should accommodate future increases in top of pavement grade due to pavement overlays and/or pavement recycling, therefore minimizing subsequent need to reduce shoulder widths. The proposed pavement rehabilitation strategy should be reviewed to determine if rounding widths larger than desirable values below are required.

Design Speed (km/h)	Desirable (m)	Minimum (m)
≥ 100	1.5	1.0
< 100	1.0	0.5

Table 2-8: Desirable and Minimum Rounding Widths

POLICY: On Major Capital Expansion Projects, desirable rounding widths should be according to Table 2-8. At locations where barrier systems are required, rounding widths are dependent on the functional foundation requirements of the selected barrier system and the steepness of the adjacent foreslope.

Chapter 4 provides functional foundation requirements for each barrier system.

2.3.4 Drainage Ditches

The primary function of a roadside drainage ditch is to collect and convey water along the highway right-of-way until it can be drained away from the subgrade of the roadway, and in most cases along the right-of-way. Ditches are designed to carry the design run-off and to accommodate excessive storm water flows with minimal flooding or damage. However ditches should also be designed, built and maintained with consideration for roadside safety.

For high speed roadways, desirable foreslope and backslope configurations for V-ditches and Trapezoidal ditches are provided in Figures 2-7 and 2-8.

POLICY: **On Major Capital Expansion Projects, desirable traversable roadside ditch configurations on high speed arterial roads and freeways should be according to Figures 2-7 and 2-8. At locations where roadside barrier systems are proposed, ditch configurations may be based solely on hydraulic and maintenance requirements.**

On Major Capital Reconstruction Projects, desirable traversable roadside ditch configurations on high speed arterial roads and freeways should be according to Figures 2-7 and 2-8 when cost beneficial. At locations where roadside barrier systems are proposed, ditch configurations may be based solely on hydraulic and maintenance requirements.

Appendix A provides severity indices for various ditch depth and shape configurations including surface types for a range of design speeds.

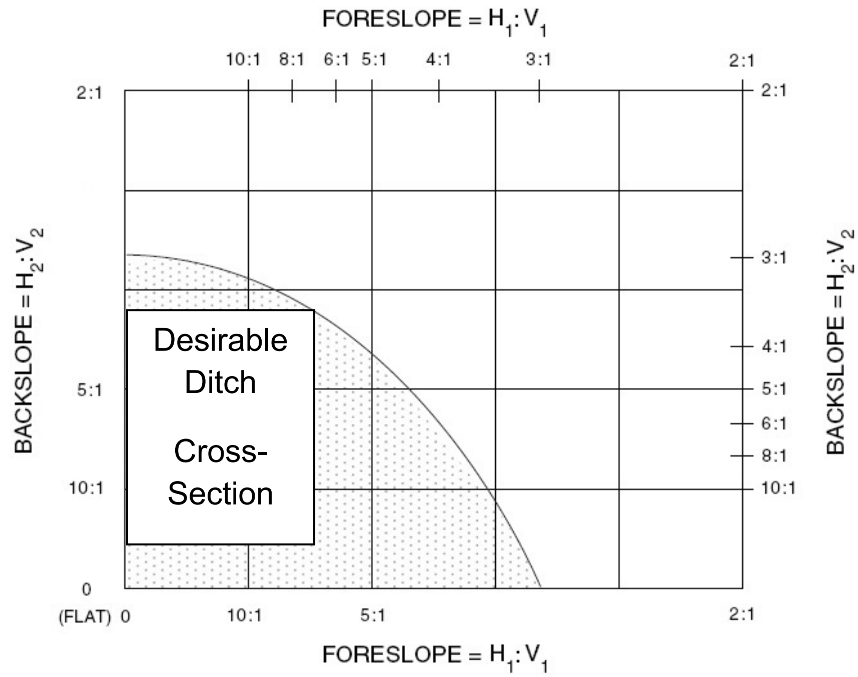


Figure 2-7: Desirable Cross-Section for 'V' Ditches on High Speed Roads

Figure based on AASHTO Roadside Design Guide.

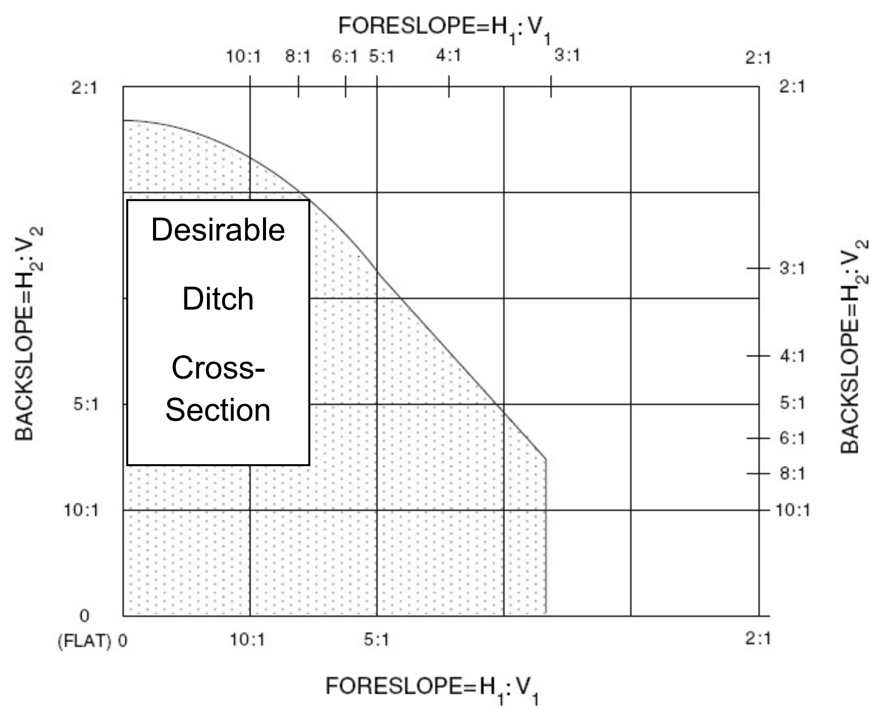


Figure 2-8: Preferred Cross-Section for Trapezoid Ditches on High Speed Roads

Bottom Width of Ditch ≥ 1.2 m

Figure based on AASHTO Roadside Design Guide.

2.3.5 Rock Cuts

Desirable rock face offset requirements for rock fall catchment purposes, as measured from the edge of the travelled way, is related to the rock cut height. Tables 2-9 and 2-10 provides the desirable rock face offset requirements and desirable ditch depth requirements to reduce the potential of rock fall material landing or coming to rest on the highway travelled way.

Rock Cut Height: h (m)	Desirable Rock Face Offset for Rock Fall Catchment: c (m)
10 to 12	5.0 to 6.0
> 12 to 14	6.5 to 7.0
> 14 to 16	8.5
> 16 to 18	10.0
> 18 to 20	11.0
> 20 to 22	12.0
> 22 to 24	13.0
> 24 to 26	14.0
> 26	15.0

Table 2-9: Desirable Rock Face Offsets

Rock Cut Height: h (m)	Desirable Ditch Depth for Rock Fall Catchment: d (m)
10 to 18	0.75
>18 to 20	1.0
>20 to 22	1.25
>22 to 24	1.5
>24 to 27	1.75
>27	2.0

Table 2-10: Desirable Ditch Depth at Rock Cut

Rock Cut Height (h) is the maximum height of the rock cut and measured vertically from bottom of ditch to top of rock cut as shown in Figure 2-5.

Desirable rock face offset for rock fall catchment (c) is the distance measured horizontally from the edge of the travelled lane or auxiliary lane to the toe of the rock face as shown in Figure 2-5.

Desirable ditch depth for rock fall catchment (d) is the depth of the ditch measured vertically from bottom of ditch to the outside edge of shoulder.

POLICY: **On Major Capital Expansion Projects desirable rock face offset and desirable ditch depth for rock fall catchment on high speed arterial roads and freeways should be according to Tables 2-9 and 2-10.**

On Major Capital Reconstruction Projects desirable rock face offset and desirable ditch depth for rock fall catchment on high speed arterial roads and freeways should be according to Tables 2-9 and 2-10 when cost beneficial.

2.3.6 Freeway Medians

New freeways are desirably designed with a depressed median of sufficient width with 6H:1V slopes to allow the roadbed to drain into the median and provide separation between opposing directions of travel. The minimum width of medians on new 4 lane or 6 lane freeways and freeway extensions is 23 m as shown in Figure 2-9. The desirable width on new 4 lane freeways and freeway extensions is 30 m as shown in Figure 2-10. A 30 m width can accommodate future staged widening into the median for 6 lanes with minimal or no impact on interchanges or flyovers or adjacent land use. These widths should be adjusted upward to account for future buffer zones between high occupancy vehicle lanes and general lanes if the ultimate configuration includes high occupancy vehicle or other managed lanes. On new highways, or highways being widened on the inside, freeway medians narrower than 23 m shall have either parallel runs of single-sided Test Level 4 (TL-4) barrier system or a single run of high-tension cable median barrier adjacent to one platform.

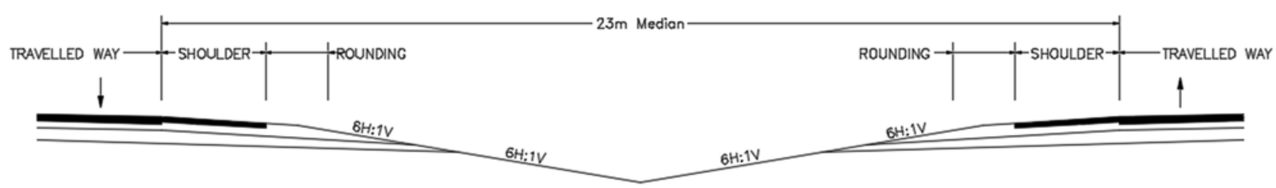


Figure 2-9: Minimum Median Configuration

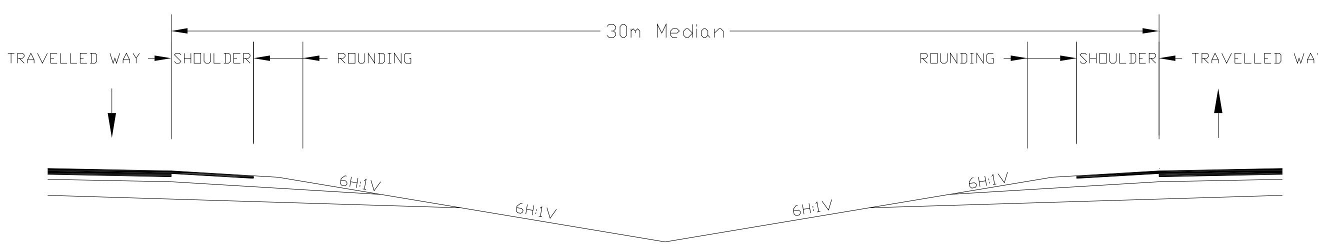


Figure 2-10: Desirable Median Configuration

Where it is necessary to minimize the footprint on new 4 lane or 6 lane freeways and freeway extensions in specific locations due to significant environmental constraints, the minimum width of median is 7.5 m as shown in Figure 2-11. The 7.5 m width includes a TL-5 tall wall median concrete barrier and provides 3.35 m wide median shoulders, which can be reduced to a minimum width of 2.5 m at bridge piers, high mast lighting poles, or overhead signs.

Where the terrain is extremely rolling, the adjacent land is not environmentally sensitive/significant, and acquisition of additional right-of-way is not a significant constraint, a wide variable median with a minimum width of 45 m should be considered as shown in Figure 2-12. The additional median width permits the use of independent roadway alignments, both horizontally and vertically, to its best advantage in blending the freeway into the natural topography. The remaining median width beyond the desirable clear zone may be left in its natural state of vegetation, trees, and rock outcroppings to reduce maintenance costs and add scenic interest to passing motorists. Staged construction of additional lanes in the median or on the outside should be considered during the Route Selection stage to ensure initial grading will accommodate future widening to the ultimate lane configuration and sufficient right-of-way is acquired.

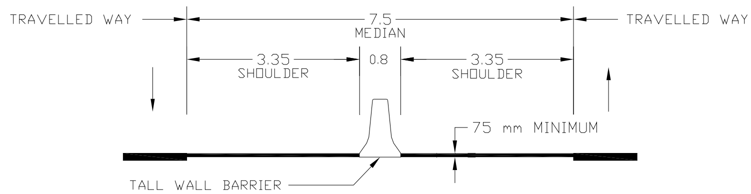


Figure 2-11: Minimum Narrow Median Configuration

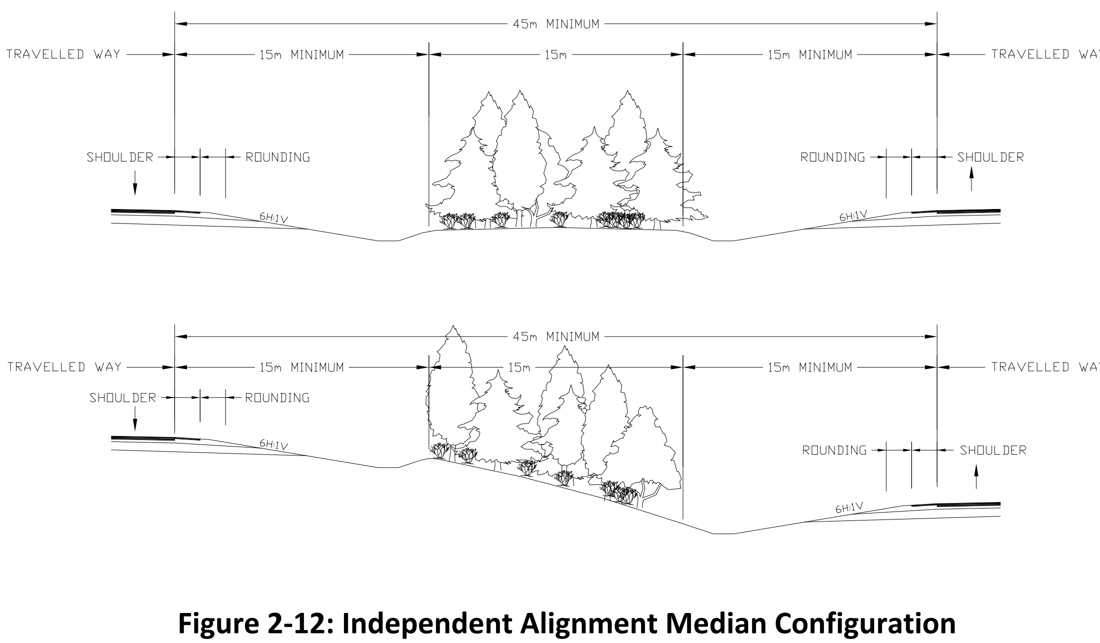


Figure 2-12: Independent Alignment Median Configuration

Median shoulder widths should not exceed the width of the adjacent through lane by more than one increment of 0.25 m.

Barrier system(s) may be installed in existing medians between opposing lanes of traffic on divided highways (in the centre median) and between parallel roads, such as collector lanes, ramps, and frontage (service) roads (in the outer median). The primary function of a barrier system in a median is to separate traffic and to contain and redirect errant vehicles. Dependent on width of the median, a median barrier system may be used which is designed to be impacted from either side of median, or roadside barrier systems may be used on each side of the median which are designed to be impacted from only one side.

Installation of median barriers should greatly reduce the number of serious cross-median collisions between vehicles travelling in opposite directions. However, installation of median barriers will generally result in significant increases in reported collisions, especially during winter storm events. This is primarily due to the reduction of the recoverable area that the relatively wide depressed median provided for errant vehicles.

POLICY: On Major Capital Expansion and Reconstruction Projects, median configurations on freeways should be according to Table 2-11.

Median Width (W)	Freeway Median Configuration
W <= 10 m	TL-5 (tall wall or equivalent) median barrier required. A lower test-level barrier system may be considered if existing and projected truck traffic volumes are low
10 m < W <= 15 m	TL-4 barrier required, either parallel runs of single-sided barrier or a single run of high-tension cable median barrier (Note 1)
15 m < W <= 23 m	TL-4 barrier required, either parallel runs of single-sided barrier or a single run of high-tension cable median barrier (Note 2)
23 m < W	Median barrier not normally considered

Note 1: A benefit/cost evaluation and an engineering study should be conducted to determine the type of barrier(s) to be installed. The evaluation should include the following factors: traffic volumes, vehicle classifications, median crossover collision history, vertical and horizontal alignment relationships, and median/terrain configurations. Potential prioritized locations may be on horizontal curves, long grades, or within limits of interchanges.

Note 2: For locations on existing highways with median widths greater than 15 m and history of higher than provincial average cross-median crashes, a benefit/cost evaluation and an engineering study should be conducted to determine the type of barrier(s) to be installed. The evaluation should include the following factors: traffic volumes, vehicle classifications, median crossover history, crash incidents, vertical and horizontal alignment relationships, and median/terrain configurations. Potential prioritized locations may be on horizontal curves, long grades, or within limits of interchanges. New highways constructed with medians less than 23 m should have a median barrier.

Table 2-11 – Freeway Median Configurations

2.3.7 Freeway Median Crossovers and Openings

To avoid extreme adverse travel for emergency and law-enforcement vehicles, emergency crossovers on freeways with depressed medians are normally provided where interchange spacing exceeds 8 km. Maintenance crossovers may be required at one or both ends of interchange facilities, depending on interchange type, for the purpose of snow removal and de-icing operations, and at other locations to facilitate maintenance operations. When required, maintenance or emergency crossovers should not be located closer than 450 m to the end of the speed-change lane of a ramp or to any structure. Crossovers should be located only where desirable stopping sight distances are provided and should not be located on superelevated curves. Median crossovers are unacceptable on freeways with narrow medians less than 15 m wide.

The width and surface of the crossover should be sufficient to accommodate and support the turning movements of the maintenance equipment used on it. The crossover should be depressed below shoulder level to be inconspicuous to traffic and should have 10H:1V or flatter foreslopes perpendicular to traffic to minimize effect to errant vehicles. Where parallel culvert(s) are required under the crossover to convey drainage in median ditch through the crossover, the foreslope perpendicular to traffic may be steepened to 6H:1V to accommodate safety slope treatments on the culvert(s). Alternatively, ditch inlet(s) or cross culverts could be considered to convey drainage under one side of highway to outlet in a roadside ditch, eliminating need for parallel culvert(s) under the crossover. Shifting proposed location of crossover to coincide with a crest curve or near a high point in median ditch grade could eliminate need for culvert(s) at the crossover.

Median barrier systems are provided to separate traffic and to redirect errant vehicles. In most cases, the traffic is travelling in opposite directions at a high rate of speed, particularly on freeway facilities.

An opening in the median barrier system for emergency services or other purposes violates driver expectations and could result in a serious collision as emergency vehicles (or illegal users) change speeds or turn to make the crossover manoeuvre. The provision of openings in median barriers in narrow medians significantly increases the risk to the travelling public, results in a discontinuity in TL-5 median protection, and would likely exceed the benefits attributable to such an opening.

For medians wider than 15 m with median barriers or roadside barriers on both sides of median, providing openings in the median barrier for crossovers is not desirable for reasons mentioned above. While the wider median can be configured to accommodate median crossovers, there will be a gap in median protection between each end of the median barrier on either side of the crossover. These crossovers should only be provided when formally requested by emergency services and by maintenance for winter operations.

POLICY: **On Provincial Highway Projects, openings in median barrier systems on freeways with medians less than 15 m wide should not be permitted. Openings in median barrier systems on freeways with medians wider than 15 m may be permitted when formally requested by emergency services or by maintenance for winter operations supported by a documented engineering analysis.**

2.3.8 Ramp Bullnoses

The bullnose exit from a freeway or arterial road represents a critical area for the driver. The grading requirements in this area are unique due to the intersection of the foreslopes supporting the freeway or arterial roadway and the foreslopes supporting the ramp. A relatively flat, firm, and smooth traversable surface with foreslopes 6H:1V or flatter is desirable beyond the bullnose within the area defined by the overlap of the desirable clear zone for the freeway or arterial roadway and the desirable clear zone for the ramp, and for a distance equivalent to the encroachment length provided in Table 2-12 measured from the gore bifurcation point as shown in Figure 2-13.

Design Speed Of Through Roadway (km/h)	60	80	100	110	120	130
Gore Encroachment Length (m)	45	75	105	135	160	200

Table 2-12: Encroachment Length in Gores at Exits

In some cases, the relatively flat surface will not be practical, due to the presence of other obstacles, such as signs, piers, abrupt slope transitions, or extreme topography. A barrier system or crash cushion should be provided to shield these obstacles if the desirable grading cannot be accommodated.

Curb at bullnoses on high speed roadways is discouraged and only mountable curb is permitted if required for drainage purposes.

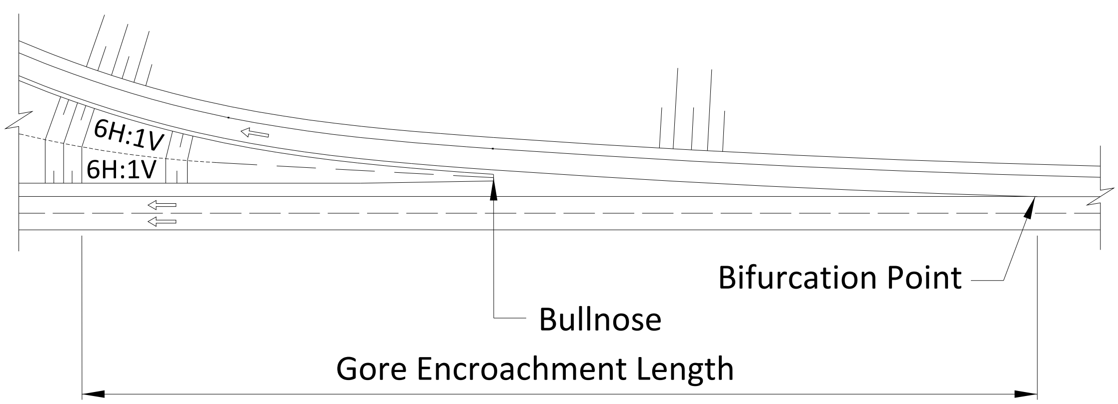


Figure 2-13: Clear Traversable Area Beyond Ramp Bullnose

POLICY: **On provincial Highway Projects, the area beyond the exit ramp bullnose from high speed roadways should be traversable and free of obstacles for a distance according to Table 2-12 measured from the bifurcation point, or protected by a barrier system or crash cushion.**

2.3.9 Curbs

Curbs are commonly used to control drainage and reduce maintenance operations. They are classed as either Type I, Type II or Type III with Type I being the tallest and Type III the shortest. These were formerly referred to as barrier, semi-mountable and mountable curb respectively. Although they are undesirable on high speed roadways, they cannot be completely avoided either on high speed or low speed roadways.

Curbs do not have significant redirectional capability above speeds of approximately 10 km/h. If an errant vehicle is spinning or slipping sideways, an impact with a curb may cause the vehicle to become airborne, or cause the vehicle to trip and roll over. The distance over which a vehicle may be airborne and the height above or below normal bumper height attained after traversing a curb may become critical if secondary crashes occur with barrier systems not designed for use adjacent to curbs.

It is often necessary, especially in urban environments to use curbs for drainage or for delineation. They are also used in low speed urban environments to discourage drivers from deliberately departing a roadway. An erosion problem may develop if surface water is allowed to drain from the roadway down the embankment. A curb may be required to channel the runoff into a catch basin, gutter outlet/spillway, or other drainage structure. Where curb is necessary on high speed roadways, Type III curb is desirable.

Curbs should not be placed adjacent to concrete barriers, since the proper performance of the concrete barrier depends on a smooth approach area between the roadway and the concrete barrier.

POLICY: On Provincial Highway Projects, Type I curb should not be installed on high speed roadways and ramps with posted speeds of 70km/h and higher, with the following exceptions:

- **Approaches to bridges with raised sidewalks;**
- **Narrow median islands with traffic signal poles, and;**
- **In conjunction with applicable barrier systems designed for use with barrier curbs at specified offsets.**

2.3.10 Water Bodies

Water bodies, as defined in the MTO Best Management Practices Manual for Fisheries, with a normal-water-level depth of 1 metre or more located within the desirable clear zone are considered to be areas of concern.

POLICY: **On Major Capital Expansion and Reconstruction Projects, water bodies with a normal-water-level depth of 1.0m or more located within the desirable clear zone according to Table 2-2 and Table 2-3 should be shielded with a barrier system.**

2.3.11 Culvert Ends

Exposed crossing culvert ends projecting beyond foreslopes within the desirable clear zone along roadways are considered to be obstacles. Errant vehicles encroaching onto recoverable slopes and non-recoverable slopes can come to abrupt stops or rollover when encountering exposed crossing culvert ends or parallel culvert ends. Various grading design and safety end treatment alternatives are available to minimize probability of impacts by locating culvert ends beyond the desirable clear zone or modifying ends to make them traversable. These options should be considered and evaluated early during hydraulic design of culverts prior to finalizing the length of new culverts and culvert extensions to determine if alternative grading options and safety end treatments can result in a cost beneficial design without having to specify a barrier system to shield the culvert end.

POLICY: On Major Capital Expansion and Reconstruction Projects, new culverts, replacement culverts, and culvert extensions on high speed roadways should be designed with end treatments as follows based on a benefit cost evaluation:

1. **Parallel culverts and exposed crossing culvert ends and sides projecting from foreslopes should be located fully beyond the desirable clear zone according to Table 2-2 and Table 2-3;**
2. **Crossing culvert ends located within the desirable clear zone should match the slope of the foreslope and be traversable with safety slope end treatments;**
3. **Safety slope end treatments for crossing culverts on foreslopes with openings greater than 750 mm should include longitudinal safety bars;**
4. **Safety slope end treatments for parallel culverts within the desirable clear zone should include transverse safety bars with 6H:1V slopes; or**
5. **Shielded with a barrier system**

2.3.12 Poles, Sign Supports and Other Roadside Equipment

Roadside poles, sign supports and other equipment (like traffic signal controller cabinets) are considered obstacles, and should be evaluated and protected according to the procedures described throughout this manual.

2.3.12.1 Luminaire Supports, Signal Poles and High Mast Poles

Luminaire and high-mast lighting supports are considered obstacles, and should be evaluated and protected according to the procedures described throughout this manual.

Luminaire supports should be located according to the clear zone guidance for the maximum AADT category (≥6,000) regardless of design traffic volume and a minimum of 3.0 metres from any lane, including auxiliary lanes. Poles located within the desirable clear zone should have breakaway bases.

Traffic signal and railway crossing poles are obstacles that are generally exempt from desirable clear zone values, as the traffic control benefits they provide outweigh the risk of having poles within the clear zone, including poles in median islands. Traffic signal poles cannot generally be equipped with frangible bases or breakaway devices as any pole strike would pose a greater risk to surrounding pedestrians and vehicular traffic.

Temporary signal and lighting poles (e.g., poles for detours, construction staging, etc) should have efforts made to locate them or protect them in accordance with the policy for their permanent counterparts, however it is recognized that this may not always be possible and engineering judgement by the designer is required.

POLICY:

1. **Luminaire supports should be located beyond the desirable clear zone in accordance with Tables 2-2 and 2-3 using the maximum AADT criteria (AADT ≥ 6000), or have breakaway bases. Luminaire supports within the desirable clear zone shall be located a minimum of 3.0m measured from the edge of any through or auxiliary lane.**

2. **Where breakaway devices (i.e. frangible bases) are used on luminaire supports, they should be located in accordance with guidance in the ministry's Electrical Engineering Manual.**
3. **Traffic signal pole locations are to follow guidance in the ministry's Electrical Engineering Manual.**
4. **High mast lighting poles should be located in accordance with guidance in the ministry's Electrical Engineering Manual.**

2.3.12.2 Sign Supports

Sign supports of all sizes are considered obstacles, and should be evaluated and protected according to the procedures described throughout this manual.

POLICY:

1. **Where small, medium and large ground-mounted signs cannot be relocated out of the clear zone, they should be installed on breakaway posts or similar devices according to standards active in MTO's Contract Preparation System.**
2. **Cantilever, monotube and truss sign supports for large overhead signs should be protected behind barrier or mounted on top of concrete barrier where required.**

2.3.12.3 Utility Poles and Other Roadside Equipment

Utility poles and other equipment mounted within the highway corridor, such as traffic signal controller cabinets, are obstacles and should be located outside the clear zone where practical or shielded with a barrier as appropriate. Consideration for driver sight lines should also be given to the location of this equipment and the impact of any shielding or barriers and an assessment of the benefits made during design. Consideration should also be made to ensure maintenance personnel can safely access the equipment.

2.4 Roadside Safety Hardware

2.4.1 New Roadside Safety Hardware Installations

This policy covers requirements for new roadside safety hardware that should be met prior to being specified for use on provincial highway projects.

Crash testing guidelines and procedures are used to evaluate the impact performance of permanent and temporary roadside safety features. Performance is evaluated in terms of risk of injury to occupants of the impacting vehicle, the structural adequacy of the safety feature, the exposure of workers or pedestrians that may be behind a barrier or in the path of debris resulting from impact with a safety feature, and the post impact behaviour of the impact vehicle. MTO continues to specify roadside safety hardware that meets the crash test acceptance criteria of National Cooperative Highway Research Program (NCHRP) Report 350, “Recommended Procedures for the Safety Performance Evaluation of Highway Features” (1993), and has started to implement new roadside safety hardware that meets AASHTO Manual for Assessing Safety Hardware (MASH) (2009 and 2016). MASH supersedes NCHRP Report 350, which superseded NCHRP Report 230 “Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances“ (1981).

It is important to note that new roadside safety hardware systems that meet MASH are not automatically accepted and specified for use by MTO on provincial highway projects. Unless standard drawings for roadside safety hardware in OPSD or MTOD format along with construction specifications have been implemented in MTO’s Contract Preparation System, or have been issued by the Highway Design Office for pilot installations on specific projects, they should not to be used on provincial highway projects.

Both NCHRP Report 350 and MASH define six performance test levels (TL-1 to TL-6) that are used to evaluate impact performance of permanent and temporary roadside safety hardware and roadside features. The test levels vary in terms of vehicle characteristics (mass, centre-of-gravity, and structural properties), approach speed, approach angle, and test evaluation criteria. A brief summary of the test levels for crash testing of longitudinal barrier systems are provided in Table 2-13 and 2-14. More detailed information about crash testing procedures and acceptance criteria are available in NCHRP Report 350 and MASH.

The ongoing need for updated crash test acceptance criteria every seven to eighteen years is primarily based on changes to the vehicle fleet that continue to change each year along with increased knowledge gained from crash testing experience and in-service evaluations. MASH is the culmination of over 50 years of crash testing experience and collective judgement and expertise of professionals in the field of roadside safety design.

The parameters used for NCHRP Report 350 and MASH crash testing include impact speed, impact angle, test vehicle mass, and impact location. Each parameter represents a “worst practical conditions” for roadside safety hardware. Traditionally, impact speed and impact angle have been set at the 85^{th} percentile level. Crash test design vehicles are normally selected based upon body style and mass. Mass selected typically approximates the 2^{nd} and 90^{th} percentile for passenger vehicles, which are represented in MASH by the small 1,100 kg car and the 2,270 kg quad-cab pick-up truck. Impact locations on roadside safety hardware are typically selected to represent a critical impact point that provides the greatest probability of failure during a crash test. The combination of all these updated parameters in MASH are believed to represent a “worst practical condition” - impact speed and impact angle combination represents approximately the 93^{rd} percentile of real-world crashes. It is implicitly assumed that if roadside safety hardware performs acceptably during crash testing with the two design passenger vehicles at the specified impact angles and speed, the system should work acceptably for all impact conditions in between.

Roadside safety hardware that had been previously crash tested and accepted under NCHRP Report 350 remains acceptable for manufacture and installation on provincial highway projects and will not have to be retested under MASH. However, after January 1, 2011, the Federal Highway Administration (FHWA) in the U.S. no longer issued eligibility letters for new or revised roadside safety hardware systems crash tested according to NCHRP Report 350. Therefore since 2010, modifications to roadside safety hardware designs by manufacturers that previously met NCHRP Report 350, or new designs being developed, should have been crash tested in accordance with the revised acceptance requirements of MASH.

Since 2018, MTO has been a member of the Texas Transportaton Institution’s MASH Roadside Safety Pooled Fund. This program, which is administered by the Washington State Department of Transportation, contracts TTI to develop and crash test non-proprietary roadside hardware including guiderails, temporary barriers, bridge rails and breakaway hardware. MTO’s membership allows for participation in the development of problem statements and voting on projects for prioritization.

In the United States on December 22, 2015, AASHTO and FHWA established an implementation schedule for roadside safety hardware, requiring new permanent installations and full replacement installation of roadside safety hardware on the National Highway System (NHS) after specified dates to meet the crash test acceptance requirements of the latest edition of MASH. This implementation schedule was subsequently amended in August 2018. The original intent was for all new roadside safety system installations to be MASH compliant by December 31, 2019. Due to limited or non-existent development of MASH compliant systems in some categories, FHWA modified its policy in November 2019 allowing the use of MASH-2009 or NCHRP Report 350 systems if MASH-2016 versions are not available. MTO is also following a similar approach and has been implementing standards for MASH systems when able. Implementation dates set in the United States for installations on the NHS along with implementation dates set by MTO for installations on provincial highways for various categories of roadside safety hardware are summarized in Table 2-15.

In 2019 MTO implemented a policy in PEM-DCSO 2019-06 governing the implementation of new crashworthy roadside systems. The policy formalizes historical acceptance practice and provides a process for evaluation and acceptance of systems both with and without FHWA eligibility letters. The policy requires all new systems to have been crash tested according to MASH 2016 however if no such systems exist in a particular category then crash testing according to MASH 2009 or NCHRP Report 350 may be acceptable.

POLICY: On Provincial Highway Projects, only barrier systems, terminal systems, end treatments, transitions, crash cushions and small sign supports described in this manual with active standards implemented in the Contract Preparation System should be used for new installations, unless otherwise authorized by the Highway Design Office.

On high-speed roads with posted speed limit of 70 km/h or higher, all new installed roadside systems shall be a minimum TL-3.

Test Level	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight (kg)	Speed (km/h)	Angle (deg.)
1	820C (Passenger Car)	820	50	20
	2000P (Pickup Truck)	2,000	50	25
2	820C (Passenger Car)	820	70	20
	2200P (Pickup Truck)	2, 000	70	25
3	820C (Passenger Car)	820	100	20
	2000P (Pickup Truck)	2, 000	100	25
4	820C (Passenger Car)	820	100	25
	2000P (Pickup Truck)	2, 000	100	25
	8000S (Single Unit Truck)	8,000	80	15
5	820C (Passenger Car)	820	100	20
	2000P (Pickup Truck)	2,000	100	25
	36000V (Tractor-Van Trailer)	36,000	80	15
6	820C (Passenger Car)	820	100	205
	2000P (Pickup Truck)	2,000	100	25
	36000T (Tractor-Tank Trailer)	36,000	80	15

Table 2-13: NCHRP Report 350 Test Level Matrix for Barrier Systems

Test Level	Test Vehicle Designation and Type	Test Conditions		
		Vehicle Weight kg	Speed km/h	Angle (deg.)
1	1100C (Passenger Car)	1,100	50	25
	2270P (Pickup Truck)	2,270	50	25
2	1100C (Passenger Car)	1,100	70	25
	2270P (Pickup Truck)	2,270	70	25
3	1100C (Passenger Car)	1,100	100	25
	2270P (Pickup Truck)	2,270	100	25
4	1100C (Passenger Car)	1,100	100	25
	2270P (Pickup Truck)	2,270	100	25
	10000S (Single Unit Truck)	10,000	90	15
5	1100C (Passenger Car)	1,100	100	25
	2270P (Pickup Truck)	2,270	100	25
	36000V (Tractor-Van Trailer)	36,000	80	15
6	1100C (Passenger Car)	1,100	100	25
	2270P (Pickup Truck)	2,270	100	25
	36000T (Tractor-Tank Trailer)	36,000	80	15

Table 2-14: MASH Test Matrix for Barrier Systems

Roadside Safety Hardware	**MTO**	**FHWA/AASHTO**
W-Beam	May 27/16	Dec 31/17
Cast-in-place Concrete Barrier	Dec 31/17	
W-Beam Terminals	Sept 1/16	June 30/18
Crash Cushions	Dec 31/18	Dec 31/18
Cable Barriers - Roadside	Dec 31/16	When Available
Cable Barriers - Median	When Available	
Cable Barrier Terminals	When Available	
Bridge Rails	When Available	
Transitions	When Available	
All Other Longitudinal Barriers	When Available	
All Other Terminals	When Available	
Sign Supports	When Available	
All Other Breakaway Hardware	When Available	
Temporary Work Zone Devices	When Available	When Available

Table 2-15: MASH Implementation Schedules

2.4.2 Existing Roadside Hardware Installations

Existing roadside hardware installations on provincial highways providing acceptable in-service safety performance and system condition should continue to perform as originally intended until the end of their service life.

On Major Rehabilitation and Major Reconstruction Projects, existing steel beam guide rail and cable guide rail installations should be reviewed and evaluated according to procedures provided in Chapter 3. Justification for new installations and replacement of existing systems should be documented in a Guide Rail Evaluation Report.

POLICY: **On Major Capital Reconstruction and Rehabilitation Projects, a Guide Rail Evaluation Report should be prepared to justify new barrier installations, barrier replacements (including replacement in-kind), and/or barrier extensions.**

2.4.3 Barrier System Length of Need

The runout length is the distance from the obstacle or area of concern being shielded to the location where an errant vehicle departs from the travelled way. The methodology provided in Figure 2-14 should be used to determine the recommended approach length of a barrier system in advance of an obstacle or area of concern being shielded. Table 2-16 provides the recommended runout lengths to be used for calculating length of need.

Length of Need is the total length of barrier recommended to shield an obstacle or area of concern. It includes the approach length upstream of the obstacle (La), and for undivided roadways, the length of the obstacle or area of concern (Lh), and the approach length downstream of the obstacle for opposing traffic (La’). For divided highways and one way ramps, leaving end treatments (LET) are required downstream of the obstacle.

DESIGN SPEED (Km/h)	**TRAFFIC VOLUME – DESIGN YEAR AADT**			
	> 10,000	**5,000 TO 10,000**	**1,000 TO 5,000**	**< 1,000**
	E (m)	E (m)	E (m)	E (m)
130	143	131	116	101
120	127	116	102	89
110	110	101	88	76
100	91	76	64	61
90	81	67	57	54
80	70	58	49	46
70	60	49	42	38
60	49	40	34	30
≤ 50	34	27	24	21

Table 2-16: Runout Lengths
Modified from 2011 AASHTO Roadside Design Guide

POLICY: On Provincial Highway Projects, recommended length of need for new barrier installations should be calculated based on methodologies contained in this manual. Calculations should identify the size and severity of the obstacle or area of concern being shielded, and be retained in the project file(s).

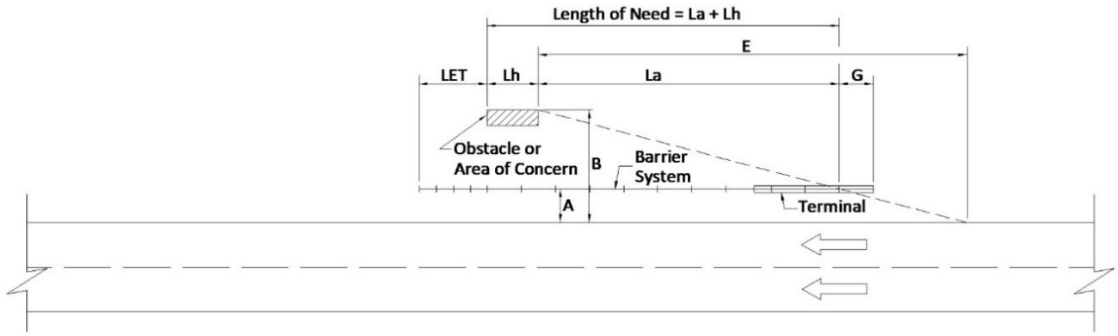


Figure 2-14: Length of Need – Divided Highway

For Divided Highway: Barrier Length of Need = La + Lh

La = E (1 - A/B) where: La = Approach Length of Barrier for Approaching Traffic
A = Distance from Edge of Travel Way to Face of Barrier.
B = Distance from Edge of Travel Way to Back of Obstacle or Area of Concern. B should not exceed Desirable Clear Zone according to Table 2-2
G = Gating length of terminal
E = Runout Length according to Table 2-16

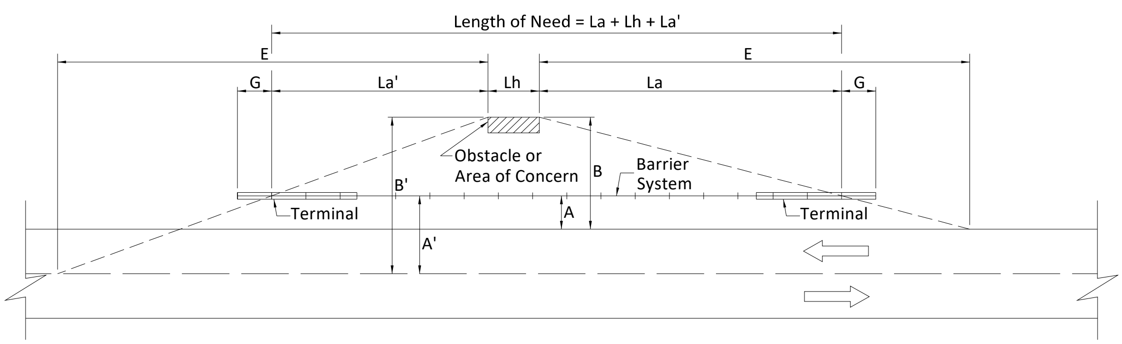


Figure 2-15: Length of Need – Undivided Highway

For Undivided Highway: Barrier Length of Need = La + Lh + La’

La’ = E (1 – A’/B’) where:La, Lh and G according to above example
La’ = Approach Length of Barrier for Opposing Traffic
A’= Distance from Centreline to Face of Barrier
B’ = Distance from Centreline to Back of Obstacle or Area Concern. B’ should not exceed Desirable Clear Zone according to Table 2-2
E = Runout Length according to Table 2-16

2.4.4 Barrier System Transitions and Connections

Barrier connections include semi-rigid Steel Beam Guide Rail transitions and connections to rigid barriers on structures, and transitions between different barrier system types. Properly designed and crash tested transitions from one type of barrier system to another are recommended to ensure continuity of protection for errant vehicles.

A proper transition design requires that the adjoining systems are compatible for deflection upon vehicle impact and that there is structural continuity in the system for distribution of impact forces and impact energy. Where deflection characteristics are significantly different between the connected systems, a gradual change in deflection stiffness is required. Risks associated with improper transition designs include pocketing (abrupt vehicle deceleration upon system impact), redirection of the vehicle back into traffic lanes and system failure due to vehicle penetration. All approved transition designs have been crash-tested or have provided many years of satisfactory in-service experience. Barrier cross-section dimensions are also considered so that snag points are not created which may pocket a vehicle and lead to rapid deceleration. Some standard transitions are intended for traffic in one direction only and exposure to opposite direction vehicle impacts would lead to problems.

No modifications should be made to any existing standard connection or transition designs. For specialized design requirements, authorization should be obtained from the Highway Design Office.

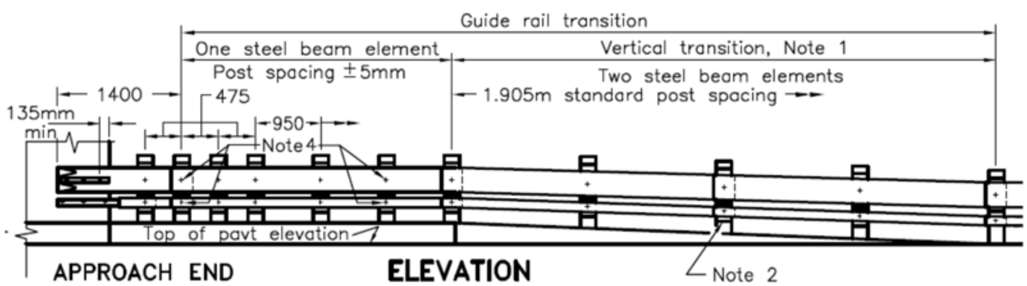


Figure 2-16: Legacy SBGR Connection to Rigid Barrier

POLICY: On Provincial Highway Projects, standard barrier system transitions and connections active in the Contract Preparation System should be used for new installations, unless otherwise authorized by the Highway Design Office.

On Major Capital Rehabilitation Projects, on high speed roadway approaches to structures, steel beam guide rail transitions and connections to rigid bridge rails not according to OPSD 912.430 should be replaced with barrier system transitions and connection standards active in the Contract Preparation System.

2.4.5 Barrier System Terminals and End Treatments

The ends of the barrier system, if left unprotected, could result in serious collisions if impacted by an errant vehicle. This is because the blunt end might penetrate into the passenger cabin, cause the vehicle to ride-over or roll over, or cause a very sudden deceleration of the vehicle. Early design attempts to address this problem included turning down and burying the end or twisting the end of the barrier system. This created other problems related to vehicles vaulting the barrier system by travelling up the sloped system element or tripping and rolling over lower parts of the end.

The development of barrier system end treatments and crash cushions addressed many concerns related to unprotected ends. While the end treatments and crash cushions vary in terms of design and configuration, most are intended to dissipate some kinetic energy and safely decelerate the errant vehicle for end-on impacts. All barrier system terminals and end-treatments are designed to redirect an errant vehicle, provided that the initial impact point is sufficiently downstream of the approach end of system.

There are two types of end treatments – gating and non-gating. They differ in how impacts near the approach end of the end treatment is accommodated. Gating end treatments permit vehicles impacting the approach end of system to pass through the end treatment to the area behind and beyond the system. Non-gating end treatments do not permit the vehicle to pass (gate) through the system after being impacted near the approach end of the terminal, but slow the vehicle by attenuating collision energy. Some end treatments will either gate or attenuate collision energy, depending on the orientation and impact angle of the errant vehicle.

POLICY: **On Provincial Highway Projects, approach ends of all new barrier system installations should be terminated and anchored by a terminal or crash cushion standard active in the Contract Preparation System.**

2.4.6 Leaving Ends of Barrier Systems

The requirement to shield the leaving end of barrier systems is dependent upon whether the highway is divided or undivided. The risk of errant vehicles impacting barrier leaving ends beyond the desirable clear zone for opposite direction traffic on divided highways is minimal especially at twin bridges where there is roadside barrier approaching the bridge on the opposite side of median. This is also true for ramps or where parallel roads are located beyond the desirable clear zone for any opposite direction traffic.

All new barrier installations on undivided highways should include a standard end treatment or crash-cushion active in the Contract Preparation System, regardless of whether the end treatment is within the desirable clear zone for opposite direction traffic.

For leaving ends of new steel beam guide rail (SBGR) that are not required to be protected by a standard treatment or crash-cushion active in our Contract Preparation System, a leaving end treatment (LET) is required. The leaving end treatment will anchor the system to resist tension forces in the SBGR resulting from vehicle impacts.

POLICY: On Provincial Highway Projects, the leaving ends of all new barrier system installations on undivided highways should be terminated and anchored by a terminal or crash cushion described in this manual.

On divided highways, a leaving end treatment should be used for steel beam guide rail installations when the leaving end is located beyond the desirable clear zone according to Table 2-2 for opposing traffic.

On divided highways, the leaving end of concrete barriers or bridge rails may be left blunt when they are located beyond the desirable clear zone according to Table 2-2 for opposing traffic.

2.4.7 Barrier Systems on Overland Flow Routes and Flood Plains

In some situations, the highway is designed to permit stormwater to overtop and flow over the driving surface during extreme storm events. This is done in the vicinity of the low-point of sag vertical curves and is referred to as relief flow. It may be appropriate where storm event flow cannot be economically or physically conveyed under the highway through a culvert or a bridge structure. The highway acts as a weir when the overtopping occurs and influences flood lines, both upstream and downstream. Permitting relief flow potentially safeguards the bridge or culvert from being washed away during a major storm event.

Barrier systems installed in relief flow locations shall permit sufficient flow at elevations close to the road surface. Impermeable, or solid-barriers such as concrete barriers would effectively act as a weir. This could result in deeper water on the highway, washout of the waterway structure and increased flooding upstream of the highway.

POLICY: **On Provincial Highway Projects, impermeable barrier systems should not extend across an overland flow route where relief flow is required across a roadway during flood events.**

2.4.8 Sign Support Systems

Signs can be classified into three groups with respect to their sizes and use of supports; these are:

- Overhead Signs
- Large Signs
- Small Signs, and
- Small Signs on Concrete Median Barrier

Overhead signs, including cantilevered signs, generally require massive support systems which cannot be made breakaway, due to load carrying requirements. Where possible, overhead signs should be installed on, or relocate to, nearby overpasses or other structures. All overhead sign supports located within the Desirable Clear Zone should be shielded with a barrier system or crash cushion. If a barrier system is used, the sign support should be located sufficiently beyond the design deflection distance of the barrier, to ensure that the barrier will function as intended when struck by an errant vehicle. Design guidance for overhead signs is found in the Sign Support Manual.

Large signs typically range in sizes from 1200mm (height) x 2400mm (width) to 2700 mm x 6000 mm (2.88m^2 to 16.2m^2). Large ground mounted signs are typically installed on two to four supports, generally of wood or steel, which may be made breakaway. If sign is installed on non-breakaway supports and is located within the Desirable Clear Zone, it should be shielded with a barrier system or crash cushion. If a barrier system is used, the sign support should be located sufficiently beyond the design deflection distance of the barrier, to ensure that the barrier will function as intended when struck by an errant vehicle. Design guidance for large signs is found in Ontario Traffic Manual Book 3.

Intermediate signs typically range in sizes from 3.6m^2 up to 7.2m^2, with sign sizes up to 3000 mm (height) by 2400 mm (width). Intermediate signs are installed using the Slip-Safe Supreme system consisting of two steel breakaway posts.

Small signs typically have a sign panel area not greater than 3.6m^2 and sign sizes range up to 1500 mm (height) x 2400 mm (width). Although not usually perceived as an obstacle, on high speed highways small signs can cause significant damage to errant vehicles during impacts. Small sign supports are manufactured using wooden or steel posts, and are available in either breakaway or non-breakaway configurations. Small signs with a sign panel area not greater than 1.35 m^2 (up to 0.9m wide by 1.5m high) may be mounted on the top of concrete median barrier using a sliding base and chute design.

POLICY: **All new small and intermediate sign support system installations on high speed roadways located within the desirable clear zone according to Table 2.2 on provincial highway projects should be breakaway**.

All new small sign support systems installations on top of concrete median barrier with top width less than 1.0 m shall use the sliding base and chute design.

2.4.9 Anti-Glare Screens

Glare from the headlights of traffic travelling in the opposite direction may be a concern on sections of divided highway with relatively narrow medians and/or high traffic volumes. This situation can also occur when parallel frontage and service roads are located close to the highway. Tall Wall Concrete Median Barrier systems often have sufficient height to reduce the glare from the majority of oncoming vehicles. For other barrier systems, anti-glare screens or vanes which fasten to the top of the barrier system have been developed. At edges of right-of-way, anti-glare screens are available that attach to chain link fence

The various anti-glare screens available are usually expensive, often exceeding the cost of the barrier system itself. Damage can result from incidental contact by vehicles or by snow and ice thrown by snow plows. For these reasons anti-glare screens should only be considered on a retrofit basis to address existing operational problems.

On new facilities, potential glare problems should be addressed by appropriate horizontal and vertical alignment design, or by appropriate barrier system selection.

On temporary concrete barriers, anti-glare screens should not be added as they may affect safety performance of the temporary concrete system during impacts by errant vehicles.

POLICY: **On Provincial Highway Projects, glare screens should be provided to improve visibility where identified operational problems with headlight glare are documented, are cost beneficially justified, and standards are active in the Contract Preparation System.**

2.5 Temporary Construction Barrier Systems in Work Zones

For construction work zones where temporary construction barrier systems are required to provide positive protection between vehicular traffic and the work area and workers, Chapter 5 provides design guidance for selection and installation of acceptable temporary construction barrier systems and terminals for use on provincial highway projects. Installations of these temporary systems also need to comply with guidance provided in OTM Book 7 and according to the Ontario Occupational Health and Safety Act.

POLICY: **On Provincial Highway Projects, only temporary construction barrier systems, transitions, restraint systems, and terminals described in this manual with standards active in the Contract Preparation System should be used for temporary installations in work zones unless otherwise authorized by the Highway Design Office.**

2.5.1 Temporary Construction Barrier Adjacent to Excavations and Roadway Protection Systems

Ontario Regulation 213/91 Section 233(1) of Part III, Excavations, General Requirements, states “a level area extending at least one metre from the upper edge of each wall of an excavation shall be kept clear of equipment, excavated soil, rock and construction material”.

Temporary construction barrier (TCB) systems are designed and crash tested for placement on paved surfaces, and paved surfaces should extend at least one metre beyond the back of unrestrained TCB systems. For restrained TCB systems, the level paved surface should be such that the barrier will perform adequately when impacted. Requirements for each barrier configuration are provided in standard drawings.

For TCB installations adjacent to roadway protection systems (support systems), a level paved area extending at least one metre from the back side of the TCB to back side of the protection system should be provided to accommodate deflection of the system when impacted. For restrained TCB systems, this paved surface width may be reduced according to applicable standards in CPS to provide adequate clearance between the back side of the TCB and back side of the protection system. For Type X TCB systems on low speed single lane installations controlled by temporary traffic signals resting in red and regulatory posted speed limits less than 70 km/h, the paved surface width may be reduced to provide at least 0.4 m clearance between the back side of the TCB and back side of the protection system.

Permanent steel beam guide rail systems may be installed as temporary barrier systems on gravel shoulders or detours as an alternative to TCB systems which also require a level area extending at least one metre from back side of the system to edge of excavation or back side of a roadway protection system.

POLICY: **On Provincial Highway Projects, when a temporary construction barrier system is specified adjacent to an excavation, a level area extending at least one metre from the upper edge of each wall of the excavation should be provided behind the backside of the temporary construction barrier system.**

In constrained areas where it is necessary to reduce the width of the level area behind the temporary construction barrier system to the upper edge of each wall of an excavation, during detailed design a Professional Engineer shall develop and specify staging plans and operational constraints according to Ontario Regulation 213/91 Section 3 of Part I, General Alternative Methods and Materials that will afford protection for the health and safety of workers that is at least equal to the protection that would otherwise be given.

During development of the staging plans and operational constraint, a stability analysis for each excavation not supported by a roadway protection system shall be carried out to evaluate slope stability in order to specify appropriate construction procedures, temporary construction barrier system type and configuration, time restrictions, and inspection requirements. The evaluation shall be documented in a report and memorandum sealed by a Professional Engineer for use during construction.

2.5.2 Temporary Construction Barrier Adjacent to Edge of Structures and Scaffolding

Temporary Concrete Barrier and Temporary Steel Barrier systems are designed and crash tested for placement on paved surfaces, and paved surfaces should extend at least one metre beyond the back of unrestrained TCB systems to edges of bridge decks or scaffolding. For restrained TCB systems, paved surfaces according to applicable standards active in the Contract Preparation System to edges of bridge decks or scaffolding should be provided.

POLICY: **On Provincial Highway Projects, a level paved area extending at least one metre from the backside of the temporary barrier system to the edge of a bridge deck or scaffolding should be provided.**

In constrained areas on bridge decks, low deflection temporary construction barriers should be specified according to applicable standards active in the Contract Preparation System.

In constrained areas on low speed single lane installations on bridge decks controlled by temporary traffic signals resting in red with regulatory posted speed limits reduced to less than 70 km/h, a level paved area extending at least 0.4 m from the backside of a Type X temporary concrete barrier system should be specified according to applicable standards active in the Contract Preparation System.

3. Roadside Design Process

3.1 Introduction

This chapter describes the roadside design process to be used for design of the roadside environment on provincial highway projects. The process integrates the policies from chapter 2 with the design treatments from chapter 4 to provide a traceable and repeatable design methodology.

3.1.1 Design Process

The primary objective of roadside design is to select the appropriate features and dimensions that will provide a cost beneficial design that provides a balance between safety performance, durability and operating functions for a particular highway corridor or highway segment. This is sometimes difficult to achieve because optimizing one set of functions may diminish the effectiveness of other functions. For example, a drainage ditch typically performs more efficiently if it is deep and has relatively steep sides to increase the flow depth. However, as roadside ditches are generally required adjacent to the roadway to provide positive drainage of the pavement structure and to convey surface runoff from the roadway, flatter traversable foreslopes and ditch cross-sections are desirable for roadside safety. This creates a potential conflict with the hydraulic design requirements for the ditch. The roadside design activity needs to resolve design choices such as these in a cost beneficial, clear, and consistent manner.

Factors to consider during the roadside design process include:

- Topography;
- Drainage;
- Environmental features;
- Operational and safety considerations;
- Property impacts;
- Political and financial commitments;
- Landscaping requirements, and
- Utility conflicts.

The Desirable Clear Zone (DCZ) distances from Table 2-2 are intended to achieve a balance between the safety benefit of providing a flat, smooth, firm surface with no protruding obstacles versus the possible constraints that limit the width adjacent to the travelled way. The DCZ distance is a function of design speed, Annual Average Daily Traffic (AADT), and either the foreslope or backslope of the roadside, on a tangential roadway. The DCZ distance is the width that the designer should review and try to provide or exceed in the corridor. The DCZ may vary along the highway depending upon whether the highway segment is on tangent or on a curve. The presence of a horizontal curve may influence the DCZ distance on the outside of the curve dependent on radius and design speed.

The designer should attempt to address the constraints first, whether it be the space available, environmental commitments, property restrictions, or funding, to provide the DCZ. Section 3.2.3 highlights several roadside mitigation strategies that might be considered.

In some cases, it may become apparent that the DCZ is not achievable within the corridor, or within localized segments of the corridor, even after considering a significant level of mitigation. The designer may consider an adjustment to the DCZ. This adjustment to the DCZ, should be documented in accordance with the policy in Section 2.1.2.

As design progresses, the information that is available to the designer becomes more certain and this permits further refinement of the roadside design strategy. For example, during corridor planning, the designer might only be able to determine the DCZ width for the corridor, whereas during preliminary design the designer would typically deal with the DCZ width, possible mitigation strategies, and may have determined preliminary adjustments to the DCZ width, if required.

The overall roadside design process is comprised of five basic steps:

1. Select the appropriate DCZ value from Table 2-2;
2. Identify the obstacles that exist within or just beyond the DCZ;
3. Select a mitigation strategy;
4. Document whether DCZ is available throughout project, or identify areas where it was not practical or cost beneficial to provide DCZ; and
5. Design the roadside feature(s).

Figure 3-1 illustrates the overall roadside design process.

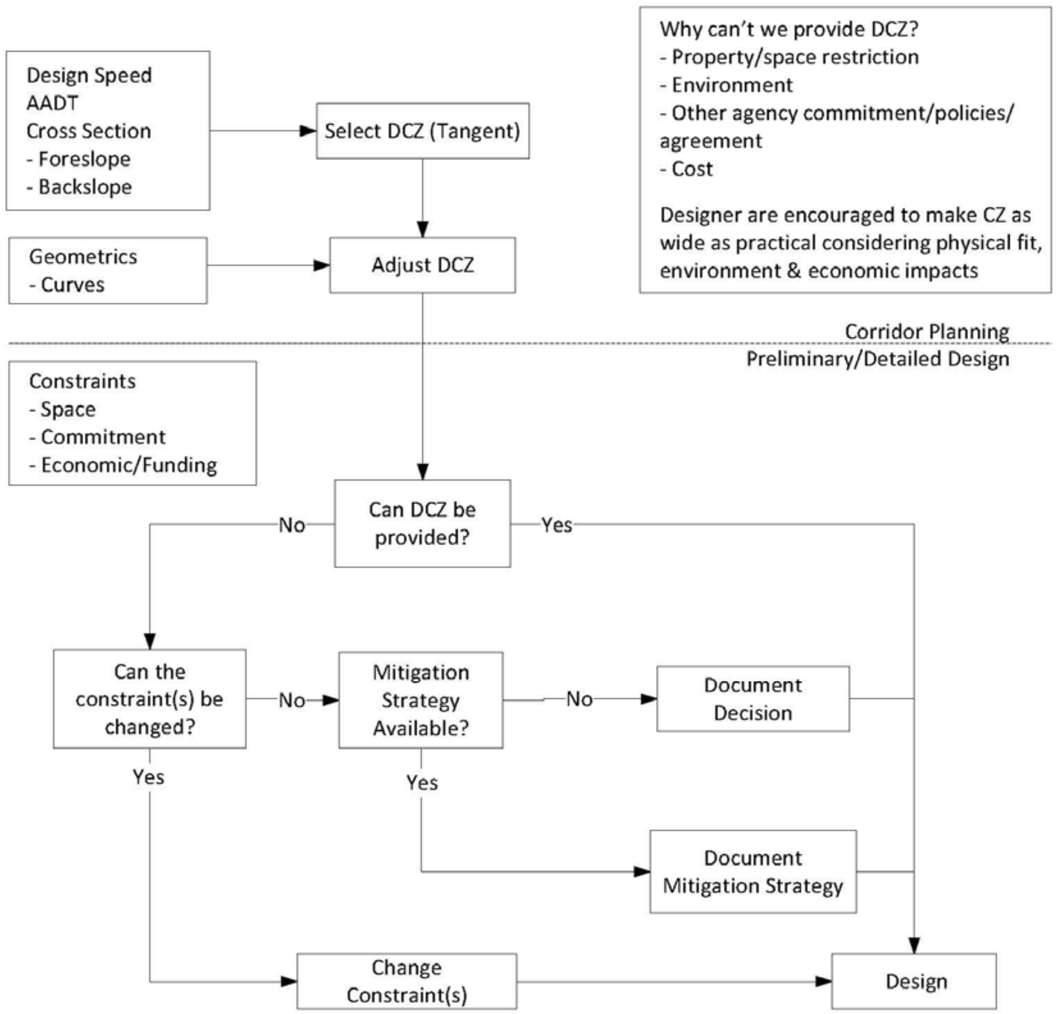


Figure 3-1: Roadside Design Process

3.1.2 Desirable Clear Zone

DCZ values from Table 2-2 are the recommended traversable obstacle free area located adjacent to the travelled way that is available for use by an errant vehicle. This border area includes paved or unpaved shoulders, bike lanes, shoulder rounding, recoverable or non-recoverable slopes, traversable features, and/or a clear runout area. The border area may be located on the outside (i.e. right side) of the highway or within the median (i.e. left side) of divided highways.

The surface within the DCZ should be relatively smooth, firm, and free of obstacles (eg., protrusions should not be greater than 100mm in size) and abrupt surface transitions to minimize negative influences on vehicle stability.

The Ministry uses a modified version of the suggested clear zone distance table from AASHTO's Roadside Design Guide (RDG). The AASHTO clear zone distance table was modified to provide a specific value, rather than a range of suggested values for each combination of the design and traffic variables, and were rearranged to illustrate the effect of slope on DCZ.

It is important for the designer to recognize that these values should only be considered as a guide when considering roadside design improvements. The DCZ does not define an absolute limit of safety. The original GM Proving Ground testing program suggested that the clear zone distance provided should be greater than the distance that most errant vehicles will likely travel off of the road. AASHTO notes that their clear zone distance values are based on limited empirical data and were extrapolated to provide only a general approximation of the needed clear zone distance for a broad range of design and traffic conditions. Recall from Figure 1-3 that a clear zone distance of 9.1 m or more on a high-speed highway with relatively flat slopes would permit about 80% of the vehicles leaving the roadway to recover. However, this also means that about 20% of the vehicles leaving the roadway will not be accommodated within the desirable clear zone (e.g., will travel beyond the DCZ). Designers should consider the safety consequences of vehicles that will travel beyond the DCZ provided, and when easily achieved and cost beneficial, exceed the DCZ.

The measurement of the DCZ distance is only applicable over recoverable surfaces (firm; 4H:1V or flatter). Non-recoverable surfaces (considered to have a falling slope between 3H:1V and 4H:1V) encountered within the roadside are traversable but generally preclude the driver from returning to the roadway. An errant vehicle will not likely stop on the steeper slope and should be expected to travel to the bottom of the slope or beyond. As such, the limit of the DCZ should be extended to compensate for the longer travel distance anticipated beyond the toe of slope. The extension of the DCZ beyond the toe of slope should be the applicable DCZ value for a

10H:1V or flatter slope, minus the sum of the width of the shoulder and half the width of the rounding; and should not be less than 3 m as illustrated in Figure 3-2.

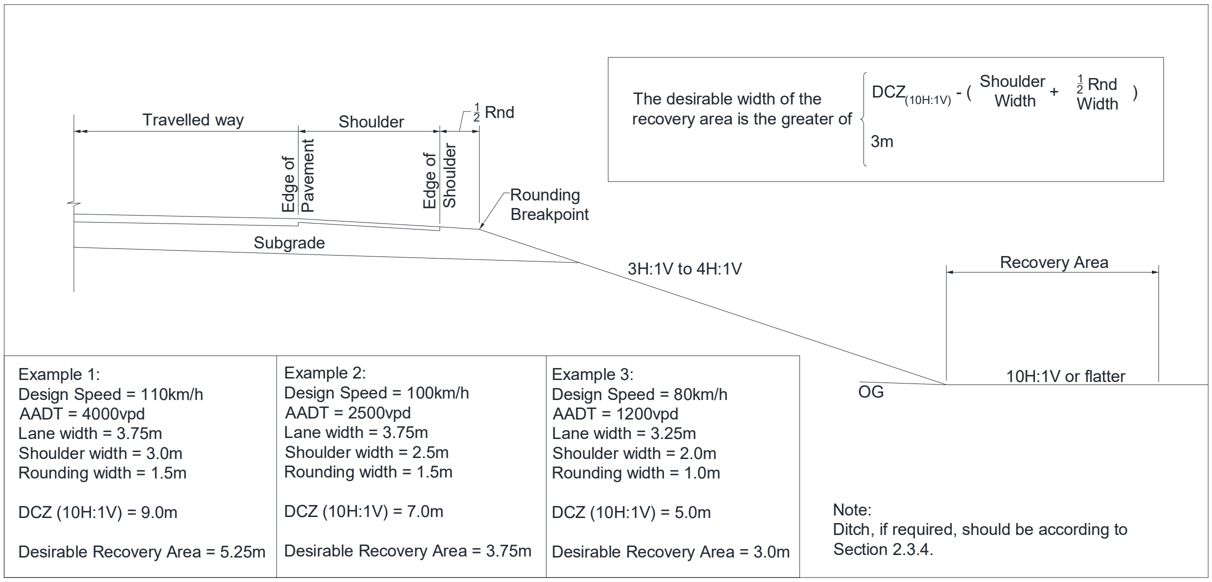


Figure 3-2: DCZ Distance on Recoverable vs Non-Recoverable Slopes

Along the outside of horizontal curves, dependent on design speed and radii, an adjustment factor to adjust the desirable clear zone distance should be applied. The DCZ for a horizontal curve is adjusted upward by multiplying the DCZ on tangent by the appropriate curve correlation factor from Table 2-3, and rounding to the nearest 0.5 m. This may or may not influence the right-of-way width.

The adjusted DCZ should be tapered from the DCZ on tangent sections to the wider adjusted DCZ on the outside of curves before and after the curve segment. The taper should be smoothly transitioned:

- Over the length of the spiral, for curves with spirals; and
- Over a 20:1 transition (with the taper length located ⅓ on curve, ⅔ on tangent), for curves without spirals.

Figures 3-3 and 3-4 illustrate how to transition the DCZ width on the outside of horizontal curves is applied.

Designers are encouraged to locate non-traversable design features beyond the DCZ and adjusted DCZ on outside of horizontal curves. Recognizing that some vehicles will likely travel beyond the DCZ, if the opportunity exists to cost beneficially locate obstacles well beyond the DCZ and adjusted DCZ, it should be considered and evaluated. For example, locating a line of hydro poles or a ditch farther away from the travelled way closer to edge of right-of-way to further reduce the probability of errant vehicle impacts can usually be accommodated. A small change like this may improve the safety of the roadway with minimal increase in cost dependent on local conditions.

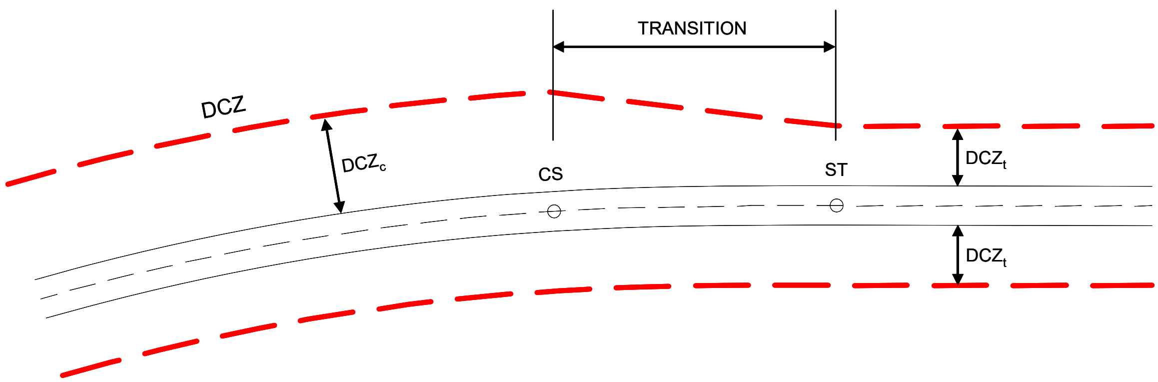


Figure 3-3: DCZ Distance Transition with Spiral

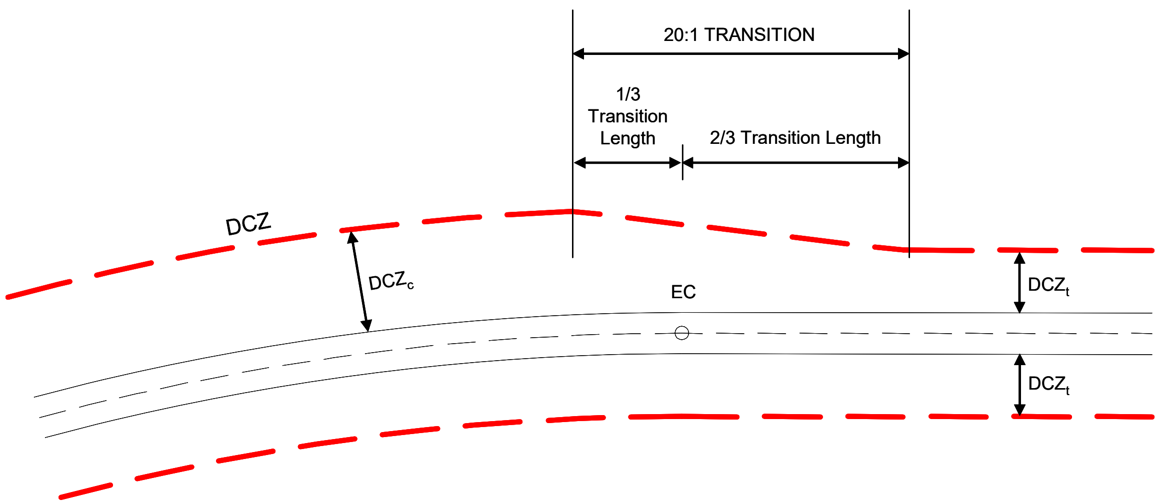


Figure 3-4: DCZ Distance Transition without Spiral

3.1.3 Identifying Areas of Concern

The next step in the roadside design process is to identify areas of concern and obstacles within or near the DCZ. An area of concern is defined as an obstacle or roadside configuration such as critical slopes that can increase the potential for personal injury and/or vehicle damage when traversed or impacted by an errant vehicle leaving the travelled portion of the roadway. Obstacles include any non-breakaway or non-traversable roadside feature typically greater than 100 mm in diameter or protrusion greater than 100mm in height located within the roadside.

The DCZ limit is plotted on the highway base plans in order to identify all of the areas of concern located within the DCZ. Figure 3-5 illustrates this process.

Potential obstacles that should be identified within the DCZ include:

- Boulders;
- Rock face/cut;
- Steep backslopes;
- Transverse slopes (including embankments and drainage ditches or channels);
- Structures including bridge abutments and piers;
- Permanent and temporary changeable message signs;
- Utility poles with non-breakaway posts;
- Traffic signs with non-breakaway supports;
- Foreslopes steeper than a 3H:1V;
- Watercourses and water bodies with a depth of 1m or more;
- Deep ‘V’ ditches;
- High fill embankments;
- Non-traversable culvert ends;
- Vegetation with 100 mm diameter and greater; and
- Non-yielding mail boxes.

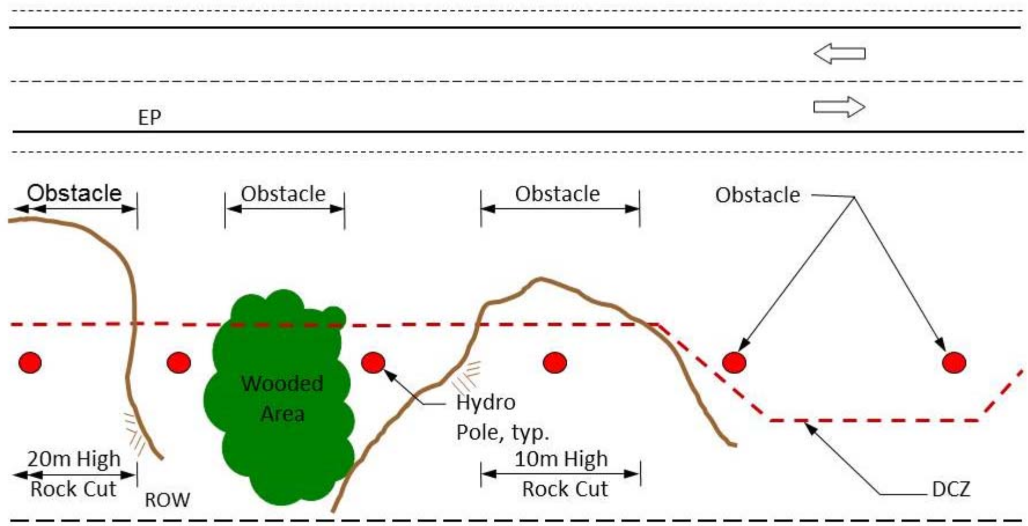


Figure 3-5: Identifying Areas of Concern and Obstacles

3.1.4 Risk Mitigation Strategies

It is recognized that the province is not always able to incorporate safety opportunities into its work program, due to physical, environmental, and/or fiscal priorities and constraints. However, the designer is encouraged to be proactive in improving safety where practical and cost beneficial. The intent of providing a desirable clear zone adjacent to the travelled way is to minimize the potential of collisions with obstacles in the roadside environment.

The designer's initial focus should be on ways to provide the full DCZ distance, fully considering physical and economic constraints, and stakeholder expectations. However, as it is not always practical and cost beneficial to provide the full DCZ distance, therefore a mitigation strategy should be employed to reduce the severity potential of impacts with roadside obstacles.

For each obstacle identified, the following strategies initially presented in Section 1.6, listed in priority of preference, should be considered to determine the appropriate roadside mitigation:

1. Remove the obstacle;
2. Relocate the obstacle to reduce the probability of it being impacted;
3. Redesign the obstacle so that it can be safely traversed;
4. Reduce the impact severity of the obstacle by using an appropriate breakaway design;
5. Shield the obstacle with a barrier system or crash cushion;
6. Delineate the obstacle, and if the above mitigation measures are not appropriate;
7. Reduce the posted speed.

Strategies to redesign, relocate, and reduce the severity of obstacles can be accomplished using the design treatments presented in Chapter 4 of this manual.

The mitigation strategy involving shielding is unique among other strategies because it adds additional design features (i.e. roadside safety hardware) to the right-of-way, rather than modifying the feature (location, and severity, delineation). The design of roadside safety hardware is a significant aspect of the roadside design process and requires special attention. Section 3.1.7 presents the design processes for roadside hardware.

3.1.5 Shielding Obstacles with Roadside Hardware

Shielding is typically accomplished by placing roadside safety hardware (barrier systems, end treatments, or crash cushions) between the travelled way and the obstacle or area of concern. The designer should recognize that the roadside safety hardware is also considered to be an obstacle. The expectation is that a collision with roadside safety hardware will be less severe, in terms of injury and damage to a vehicle, than a collision with the obstacle being shielded. This assumes that the roadside safety hardware is designed, constructed, and maintained properly.

There are several steps in the design of roadside hardware:

1. Determine the shielding requirements (Length of Need – see Sections 2.4.3 and 3.1.6);
2. Identify potential barrier system alternatives (based on location, traffic, working width – see Section 3.1.7) and select preferred hardware; and
3. Identify potential end treatment or crash cushion alternatives for the barrier system selected (based on location, traffic, working width – see Section 3.1.8) and select preferred hardware.

3.1.6 Barrier System Length of Need

The Length of Need (LON) is defined as the length of barrier system required to shield an obstacle. This length may include some or all of the length of end terminal used on the barrier system. The length of end terminal that can be used as part of the LON is dependent on where on the terminal it can start to redirect errant vehicles during an impact. The components for LON for divided highways and undivided highways are illustrated and defined in Figures 2-15 and 2-16 respectively.

The LON is the summation of the lengths of three components:

- Approach length to the obstacle;
- Length of the obstacle; and
- Leaving length after the obstacle (also considered to be the approach length for opposing traffic, where applicable).

The LON is influenced by the:

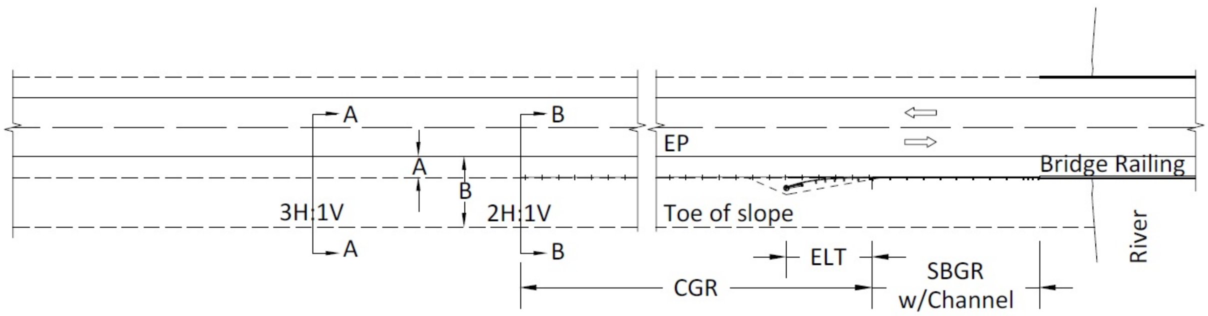
- Encroachment length that an errant vehicle is expected to travel once it has departed the travelled way;
- Distance between the back of obstacle and the travelled lanes; and
- Offset of the barrier system to the obstacle and to the travelled lanes.

The encroachment length values recommended for LON calculations are provided in Table 2-16.

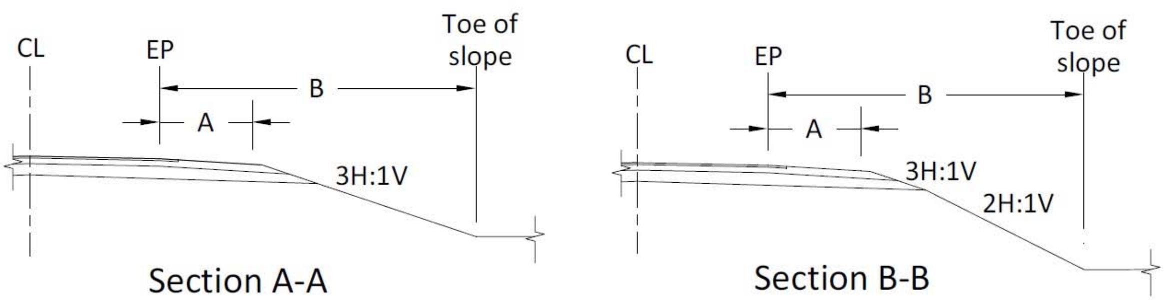
For areas of concern, such as a critical fill foreslope (steeper than 3H:1V) on the approach to a bridge, Figure 3-6 shows an existing condition on a two-lane high speed provincial highway with cable guide rail and SBGR. In this example, the existing cable guide rail is being replaced in accordance with the guidance in Section 3.3.4. The existing SBGR, structure connection and Eccentric Loader Terminal transition were in acceptable condition. As part of the evaluation, existing cross-sections taken at 25m intervals indicated that the approach end of the existing cable guide rail was located where the existing fill was 2.5m high with a 2H:1V foreslope (Section B-B). The adjacent fill section (Section A-A) 25m to the west (left) was also 2.5m high but with a 3H:1V slope.

Based on severity indices for a design speed of 100 km/h for a 2.5m high 2H:1V foreslope, a 2.5m high 3H:1V foreslope, and a roadside barrier system, the start of the area of concern is located at section B-B where the severity index for the critical 2H:1V is higher than the severity index for the barrier system. For the length of need calculation, B is equal to the horizontal distance from the edge of travelled lane to the toe of slope.

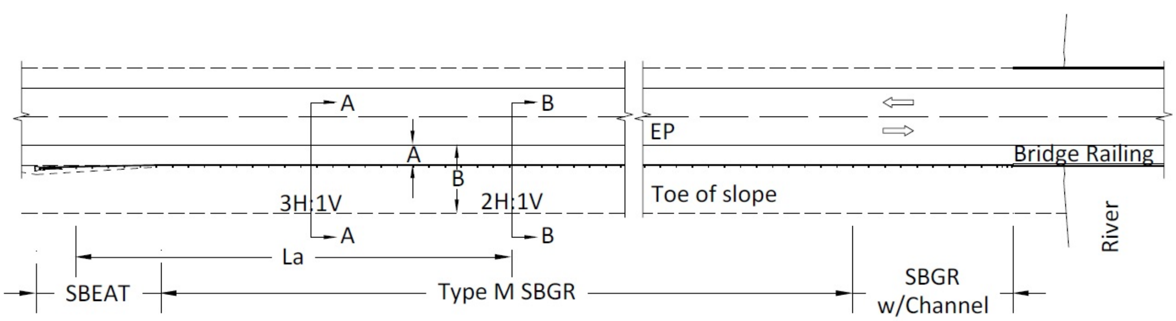
As there is currently no acceptable transition from high tension 3 cable guide rail to SBGR, the existing cable guide rail system and Eccentric Loader Terminal transition needs to be removed and replaced with Type M SBGR with an SBEAT as shown in the bottom sketch in Figure 3-6. Widening of the fill at the proposed location of the SBEAT will be required in accordance with the current standards.



Existing Condition with Existing Cable Guide Rail and SBGR on Approach to Bridge



Existing Fill Cross Sections



Proposed SBGR and LON on Approach to Critical Fill Foreslope and Bridge

Figure 3-6: Protection to Back or Bottom of Area of Concern

Obstacles located in the vicinity of interchange ramps or other adjacent roadways require special attention. The encroachment requirements for the obstacle associated with each facility should be checked to confirm the extent of mitigation required.

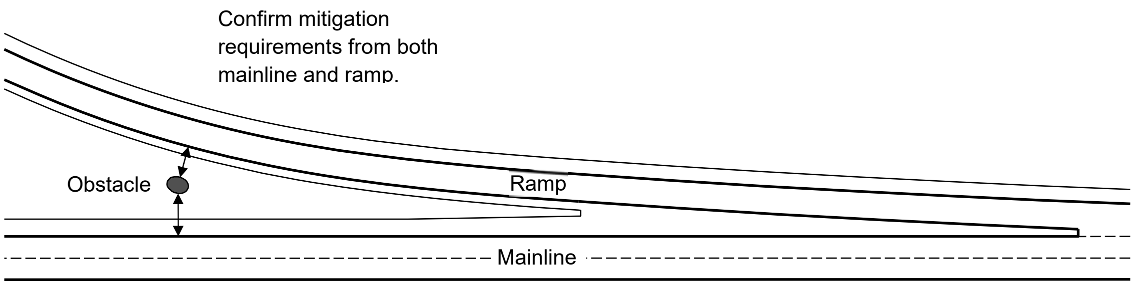


Figure 3-7: Mitigation Requirements at Exit Ramps

When multiple obstacles exist within close proximity to each other, it may be necessary to consider these obstacles as a combined obstacle because the individual LON for the obstacles may overlap or result in a small separation between the two obstacle lengths. Consider combining roadside hardware shielding applications when the:

- LON for adjacent obstacles overlap; or
- Gap between barrier systems is less than or equal to 50m.

An exception to this would be when a gap is required between adjacent barrier systems to accommodate an entrance to a property or to access a stormwater management pond. The designer should attempt to minimize the severity of an errant vehicle striking an obstacle or the ends of the barrier system after the gap by specifying an applicable end terminal active in CPS. In many cases, the need for a gap in the barrier system to accommodate entrance or access roads can be avoided by relocating the access points to the far side of the obstacle, especially on divided highways.

The encroachment length (E) for the approach end is measured from the obstacle to the:

1. Edge of the through travel lane (eg., edge of pavement between the right traffic lane or ramp and shoulder); or
2. Edge of auxiliary lane (eg., speed change or passing lane), where applicable.

The final component of the LON is the leaving end of the barrier system. On undivided highways, an encroachment length (E) for the opposite-direction traffic is required to shield the obstacle. The same encroachment length (E) are used for calculations, but are measured from the edge of lane for opposing direction of travel:

- Centerline of two-lane highways and multilane highways (without flush or raised medians);
- Edge of passing lanes (eg., between opposing traffic lanes), where applicable; and
- Edge of median for multilane highways (with flush or depressed medians).

Barrier systems on divided highways are generally not intended to shield obstacles from opposite-direction traffic, but this is somewhat dependent on how wide the median is and what, if any, cross-median shielding has been provided. Barrier systems located in a narrow median are more susceptible to opposite-direction hits and should have end treatments if they are located within the DCZ for opposing traffic and not shielded by an appropriate length of barrier.

Shy Line Offset and Barrier Flare Rates

The shy line is defined as the distance between the edge of the driving lane to the inside edge of a barrier system. Barriers placed in close proximity to the travel lane may cause drivers to feel uncomfortable, causing them to slow down and / or change positions. This can cause a reduction in capacity on high speed, high volume roadways. It is desirable that barriers be placed at or beyond the shy line offsets according to the AASHTO Roadside Design Guide, 2011 in table 3-1 below, however barriers may be placed at offsets equal to the recommended shoulder width required for the design speed and traffic volume. Barrier offset should not result in increased impact angles and barriers should always be constructed with appropriate grading requirements.

Design Speed (km/h)	Shy line offset (m)
130	3.7
120	3.2
110	2.8
100	2.4
90	2.2
80	2.0
70	1.7
60	1.4
50	1.1

Table 3-1: Recommended Minimum Shy Line Offsets

The AASHTO Roadside Design Guide recommends maximum flare rates for new permanent barriers inside and beyond the shy line. These values are presented in Table 3-2 Below:

Design Speed (km/h)	Maximum Flare Rate for Barrier Inside Shy Line	Maximum Flare Rate for Rigid Barrier Beyond Shy Line	Maximum Flare Rate for Semi-rigid Barrier Beyond Shy Line
≥ 110	30:1	20:1	15:1
100	26:1	18:1	14:1
90	24:1	16:1	12:1
80	21:1	14:1	11:1
70	18:1	12:1	10:1
60	16:1	10:1	8:1
50	13:1	8:1	7:1

Table 3-2: Recommended Maximum Barrier Flare Rates

3.1.7 Barrier System Selection

The selection of a barrier system is influenced by the type of facility, location of the system, topography, geometrics, and traffic and operational characteristics. The selection of the barrier system is based on the working width, location (median/roadside/gore), median width, offset distance from edge of travelled way to the barrier system, geometrics (tangent/curve), and the radius of curve.

Barrier systems should be used to separate opposing traffic flows where a significant risk of a cross median collision exists. Experience has shown that the risk of cross median collisions increases as the median width decreases. The Ministry’s policy for freeway medians and median barriers are provided in Section 2.3.6.

The selection of an appropriate barrier system when barriers are recommended in a median should be made using the process presented in Figure 3-8.

The working width of a barrier system governs the minimum offset between the barrier system and the obstacle that is being shielded. If the system is placed too close to the obstacle, the impacting vehicle may deflect the system into the obstacle. This may allow the vehicle to interact with the obstacle and negate the purpose of the barrier system.

A closed drainage system will likely be required with all narrow median barrier systems when median shoulders and any adjacent lanes drain towards the median.

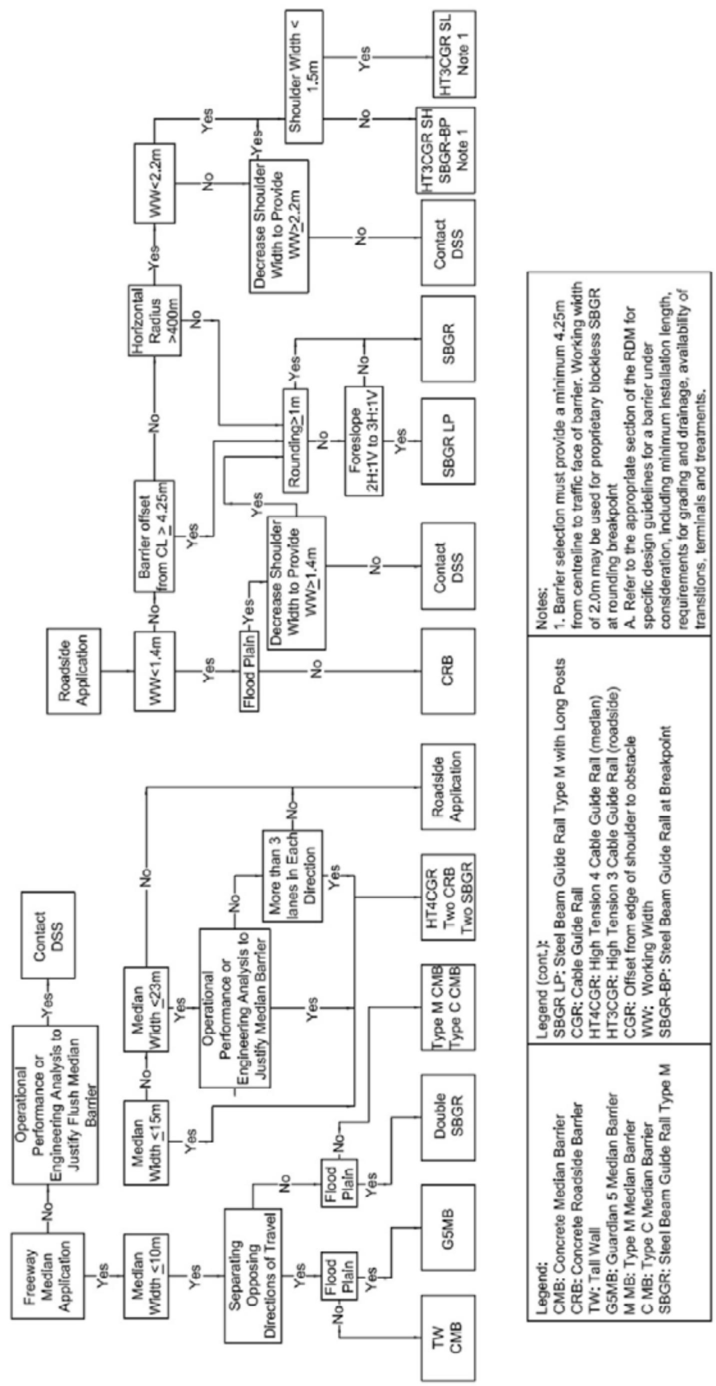


Figure 3-8 – Selection of Appropriate Barrier Systems Active in CPS

3.1.8 End Terminal and Crash Cushion Selection

Selection of end terminal or crash cushion is influenced by the type of barrier system (if applicable), type of facility, location of the end treatment or crash cushion, topography, geometrics, and traffic and operational characteristics. The selection of the end terminal or crash cushion is based on facility type (divided/undivided), location (approach/leaving end, median/roadside/gore), median width, cut/fill section, grading restrictions, geometrics (tangent or curve and radius of curve) and the size of the obstacle.

Most end treatments and crash cushions are propriety products. Some end treatments and crash cushions have similar characteristics and more than one product from one or several manufacturers may be appropriate for the same situation. As such, only general guidance is provided in the selection of an approved end treatment and/or crash cushion.

Guidance regarding the selection of end treatments and crash cushions is provided in the following sections for:

- High Tension 3-Cable Guide Rail;
- High Tension 4-Cable Median Guide Rail;
- Steel Beam Guide Rail;
- Concrete Roadside Barrier;
- Concrete Median Barrier; and
- Single Fixed Object.

High Tension Three-Cable Guide Rail:

The only end treatment standard currently active in CPS for High Tension Three Cable Guide Rail is the Safence High Tension Cable Guide Rail Terminal.

Design treatment information is presented in Section 4.3.2.2 and on the applicable standards active in CPS.

High Tension Four Cable Median Guide Rail:

There are currently two end treatments available for High Tension 4 Cable Median Guide Rail: the Gregory Safence and the Trinity HARP. Both systems meet the requirements of NCHRP Report 350. Design treatment information is presented in Section 4.3.1.

Steel Beam Guide Rail:

Figure 3-9 provides guidance in the selection of appropriate end treatments and terminals for Steel Beam Guide Rail:

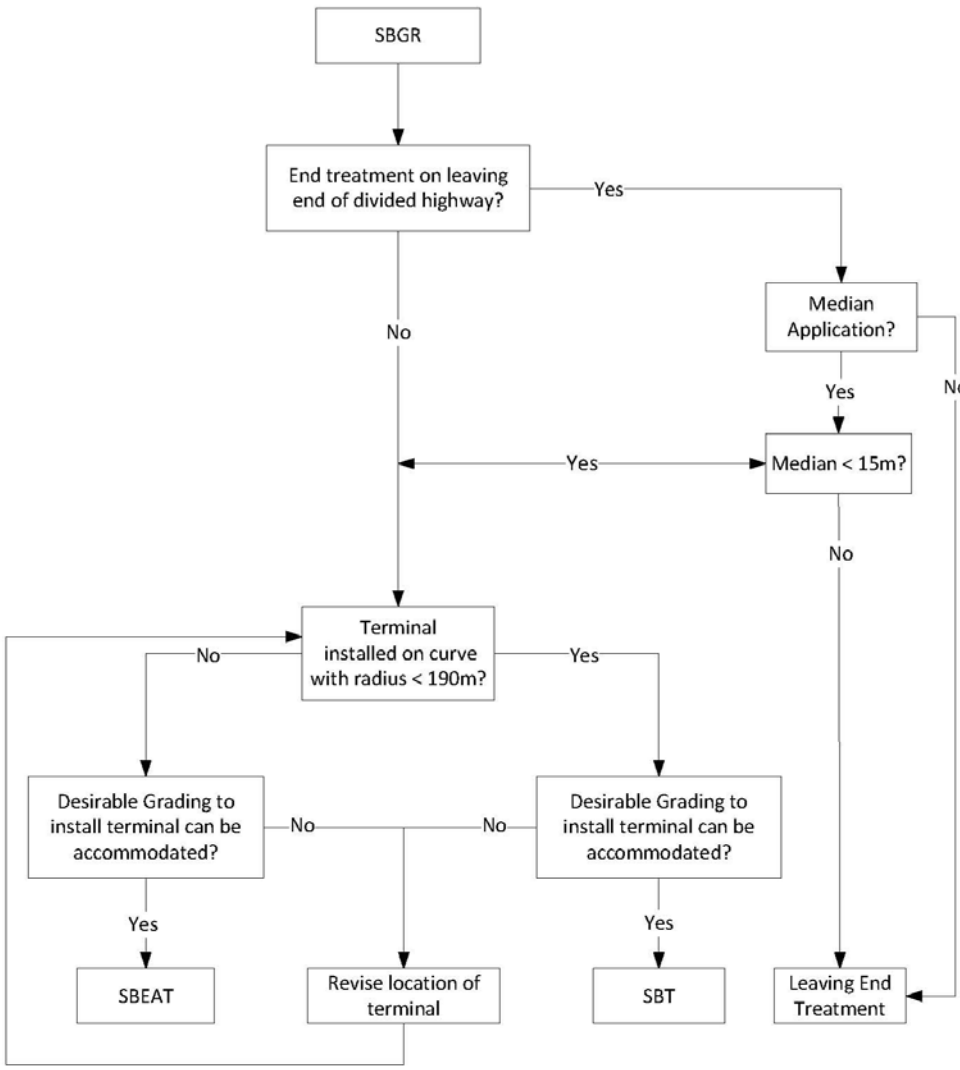


Figure 3-9 – Selection of End Treatment for Steel Beam Guide Rails

Design treatment information is presented in Chapter 4 and on the applicable standards active in CPS.

Concrete Roadside Barrier and Concrete Median Barrier:

Figure 3-10 provides guidance in the selection of end treatments and crash cushions for Concrete Roadside Barriers and Concrete Median Barriers:

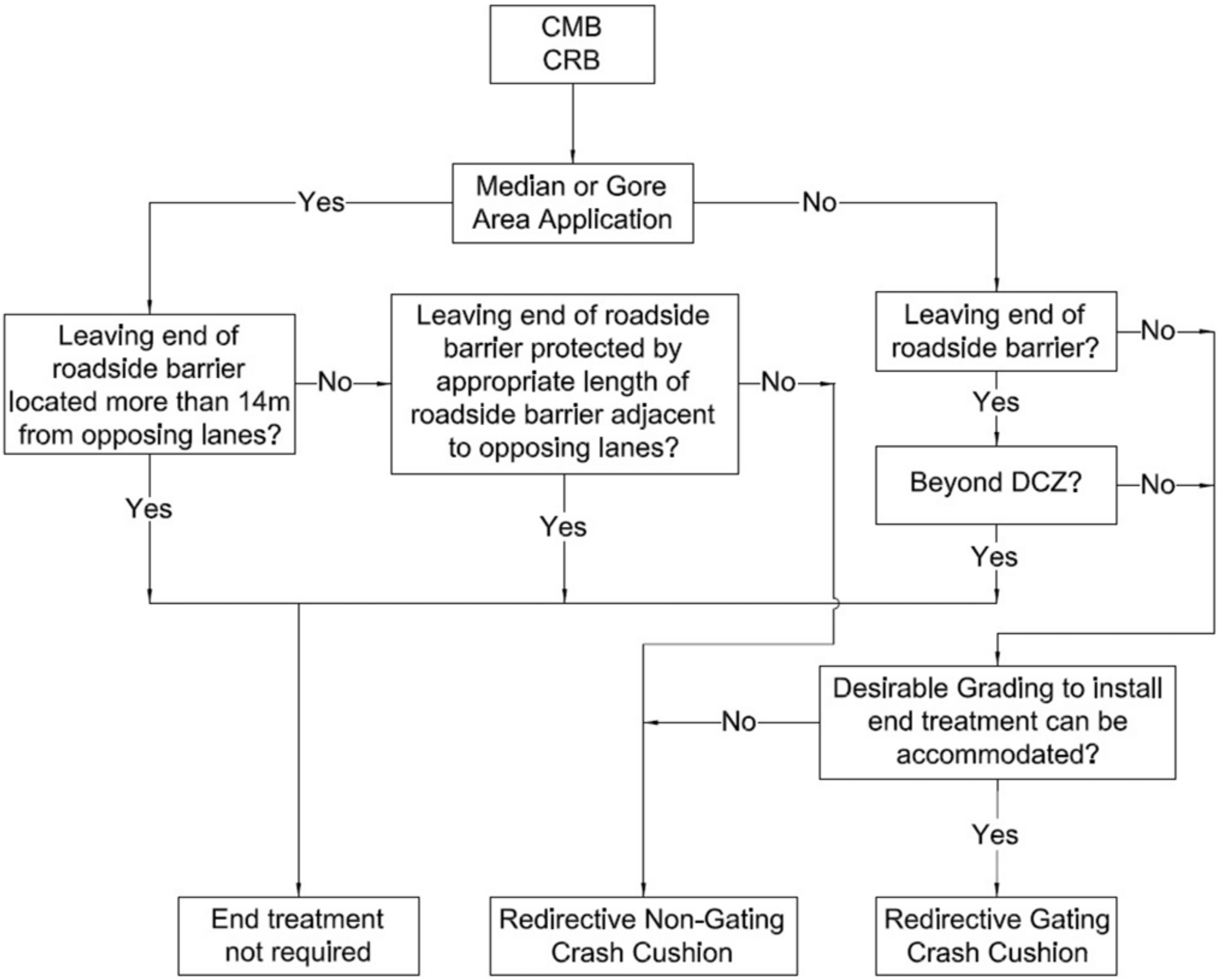


Figure 3-10 – Selection of End Treatment or Crash Cushion for Concrete Barriers

For Concrete Median Barrier, a transition section is required to properly terminate the barrier with a deeper end section and smaller end area to accommodate installation of a narrow crash cushion.

Design treatment information is presented in Chapter 4 and on the applicable standards active in CPS.

Single Fixed Obstacle:

Figures 3-11 provide guidance in the selection of crash cushions for a single fixed object located in a median, gore area, or on the roadside:

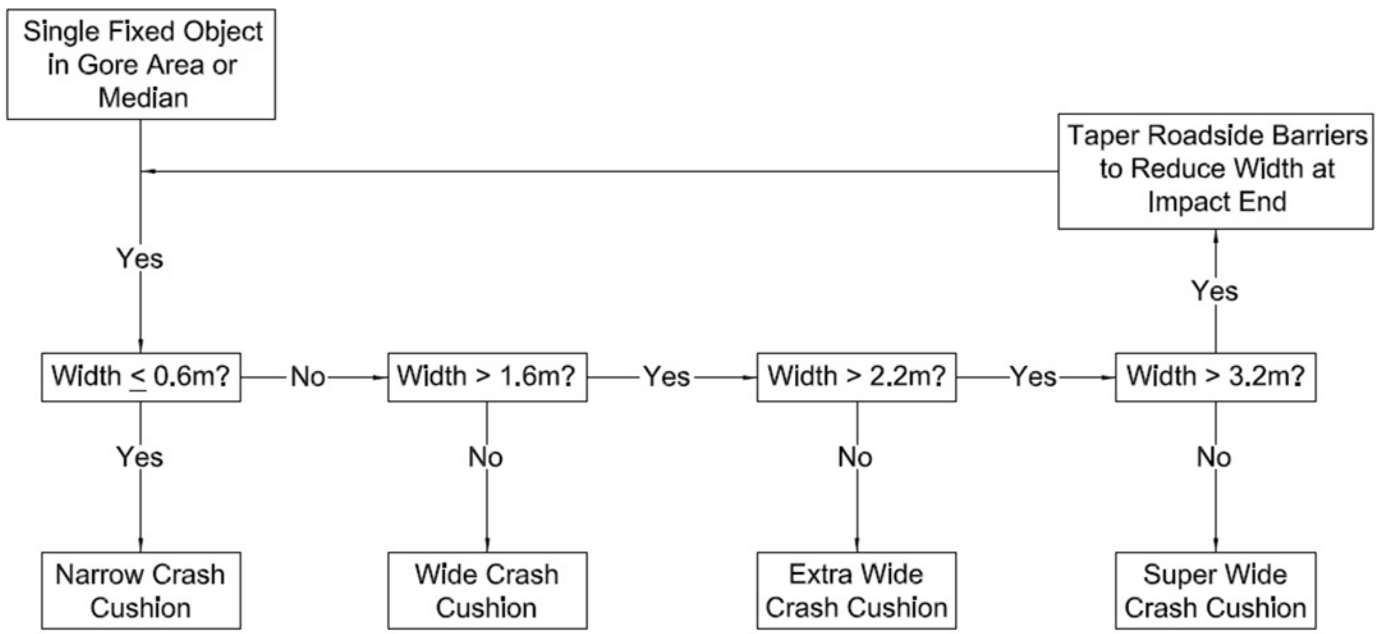


Figure 3-11: Selection of Crash Cushion for a Single Fixed Object in a Median, Gore or Roadside

Design treatment information is presented in Chapter 4 and on the applicable standards active in CPS.

3.1.9 Desirable Clear Zone

In some instances, the DCZ distance may not be available due to environmental, property, fiscal, and/or other constraints. In this situation, approval may be sought to adjust the clear zone distance for a specific segment of highway and documented accordingly in the Design Criteria. Adjusting the clear zone distance for a particular highway segment should be evaluated to ensure that it is the most appropriate strategy, and documented in accordance with the policy in Section 2.3.1.

The characteristics of the highway environment can influence the driver's decision regarding travel speed, risk acceptance, and behaviour (passing, aggressive driving, inattention, for example). The driver takes cues from the level of consistency of how the roadway looks or feels to establish a personal level of comfort that guides driver action. Human factors studies on driver behaviour suggest that the drivers can more readily adapt to a change in the highway environment if they understand that a change will occur. This is the principle behind the use of advanced signs for major decision points to increase driver awareness, or even the tightening of successive interchange ramp curves to pre-condition a driver for the stop condition at the sideroad.

This can be extended to include the design consistency of the roadside. For example, some drivers who feel comfortable travelling at normal operating speeds on a highway with a wide and open roadside, may feel less inclined to do so on highways that have a long rock cut face in proximity to the travelled way. Changing the clear zone distance for a segment of highway will likely be perceived as a noticeable change by the driver that might influence driver comfort and action.

Major obstacles that prompt a localized reduction in the clear zone distance provided should be delineated to enhance the driver's awareness of the possible changes in the roadside environment.

3.2 Benefit-Cost Evaluation

For roadside design on provincial highway projects, benefit cost evaluations should be completed using MTO's Roadside Evaluation Manual and MTO's Roadside.xlsx program.

The economic evaluation of roadside treatments is premised on a comparison of realized safety benefits and implementation costs. The avoided costs that would have been sustained by the community due to a collision associated with a particular roadside treatment are termed societal benefits. The implementation costs are the capital and maintenance expenditures required to provide and maintain the roadside treatment in a serviceable condition, generally over the service life of system or feature.

Societal benefits are calculated by estimating the anticipated cost that the community would have sustained if a collision had occurred.

Implementation costs are determined from one-time and annualized costs.

Economic factors, such as the life cycle period, discount rate, and escalation rate (if applicable), must be selected to perform the economic analysis.

3.2.1 Encroachment Rate and Probability

Obstacle modelling techniques have been in place for over 30 years. In 1974, Glennon introduced the encroachment probability model concept and this was presented in NCHRP Report 148 (Roadside Safety Improvement Programs on Freeways: A Cost-Effectiveness Priority Approach).

The encroachment probability model is built upon a series of conditional probabilities in the following form:

$$E(C) = V * P(E) * P(C/E) * P(I/C) * C(I)$$

where:

E(C)	= estimated collision cost ($CDN)
V	= traffic volume (AADT)
P(E)	= probability of an encroachment (%)
P(C/E)	= probability of a collision given an encroachment (%)
P(I/C)	= probability of an injury given a collision (%)
C(I)	= cost of an injury ($CDN – based on severity of collision)

3.2.2 Severity

The concept of severity was first introduced when cost-effectiveness selection procedures for roadside design were developed in the early 1970's. The principles of severity are:

- Collision severity, expressed in terms of a severity index (SI) is a surrogate measure of injury and property damage probability and severity;
- A severity index can range in value from 0 (no injury) to 10 (fatal injury); and
- Each design feature (such as a slope, bridge pier, ditch, roadside hardware, tree, or post) can be assigned an SI to reflect the relative differences in injury and property damage that would be sustained in similar collisions (speed, departure angle) between two or more features.

As an example, occupants in a vehicle that collides with a small tree or bush will likely sustain less injury than if the vehicle had hit a bridge pier. This is an intuitive result for this simple comparison, however, consider that a barrier may be installed in front of the tree and the bridge pier. Question: Is it cost-beneficial to install the barrier? The answer is determined through a benefit cost economic evaluation of design alternatives considering the installation cost of the barrier system versus the societal benefit (eg., the benefit to the community if the injuries were not sustained). This would require SI values to be assigned to the tree, the pier, and to the barrier system.

A set of severity tables that provides SI values for a broad range design features was included in Appendix A of AASHTO's 1996 Roadside Design Guide that is still in use by many road agencies today including MTO. The 1996 SI values have been modified with the addition of the 1991 FHWA SI values for rock cuts. The modified SI values used for provincial highway projects are included in Appendix A of this manual.

3.2.3 Implementation Costs

Implementation costs associated with roadside features typically consist of both construction and annual maintenance costs. However, it is sometimes difficult to determine the maintenance and repair costs of roadside features. As such, maintenance and repair costs are often ignored in the economic decisions even though they may result in significant costs. Rehabilitation costs are usually considered for roadside hardware. However, if reliable maintenance and repair information is available, it should be used for the evaluation.

Construction unit costs are available from the Ministry’s HiCo estimating program. The program provides a wide range of unit costs using specific contract data, and District-wide, Region-wide, and Province-wide averages. Designers should use generalized construction cost information to determine the cost of the design alternatives. Cost comparisons can be made for specific design treatments or on a per unit length (e.g. per km) basis.

Rehabilitation costs for roadside features will generally equate to replacement costs or adjustment costs (e.g. adjustment to height of guide rail systems after pavement overlays) when future work is undertaken. Costs for rehabilitation should be obtained in the same manner as the construction costs.

3.2.4 Economic Factor Selection

The Ministry's Program Management Branch is responsible to provide the discount rate used in economic analyses. The discount rate varies by year but generally averages about 6%. For consistency, it is recommended that a discount rate of 4.5% be used for economic analysis of roadside features, unless otherwise directed.

The selection of a life cycle period is also required to perform the analysis. The life cycle period should be equal to or slightly exceed the greatest expected design life of the features being considered. This permits an opportunity to fully consider the cost of feature.

In general, the following life cycle periods should be used unless directed otherwise:

- Roadside hardware: 30 years
- Grading features: 30 years
- Structural features: 50 years

These return periods are suggested because:

The service life of roadside safety hardware can vary greatly from just a few hours to several decades. The Ministry's typical pavement rehabilitation cycle occurs about every 12 to 18 years, followed by reconstruction 10 to 20 years later. During pavement rehabilitation, only significantly damaged sections of roadside safety hardware will likely need to be replaced, and other sections may need to be adjusted to ensure acceptable system heights are maintained after pavement rehabilitation (eg., overlays). After 30 years, which often coincides with road reconstruction, steel roadside safety hardware systems will likely be rusted and near the end of their service life and are generally replaced.

The return period for grading features was selected as 30 years because major reconstruction work typically occurs at this interval. The premise is that major grading activities would likely be undertaken during reconstruction work.

The return period for the structural features was selected as 50 years to reflect the relatively longer service life expected (when compared to the other types of features considered). Recently built structural features will likely last much longer than the return period selected, but older bridges reaching the end of their service life could diminish the average service life of structural features to the period selected.

3.3 Documentation Requirements

An objective of the updated roadside design process is to ensure a consistent application of the policies and design treatments across the provincial highway system. Clear documentation promotes process consistency, and this contributes to the quality of the design information generated.

It is expected that the designer will document the selection of the DCZ and the LON determined using the design process as part of a traceable design process, and for future reference, in accordance with the policy presented in Section 2.2.

Design processes that differ from those presented in this manual for roadside design require authorization from the Highway Design Office, in accordance with the policy presented in Section 2.2. The documentation requirements of alternative design processes may be different from the documentation requirements listed in this section. The Highway Design Office should be contacted to confirm the documentation requirements for alternative design processes

3.3.1 Clear Zone Documentation

Design decisions pertaining to clear zone should be documented for applicable projects in the project's Design Criteria according to Section 2.3.1.

3.3.2 Contract Drawings

For new roadways and widened roadways, for new fill and cut sections, the specified foreslopes and backslope ratios and their respective limits should be shown on the contract drawings. For rock cut sections with rock faces, the desirable clear zone and rock fall catchment dimension, as well as ditch depth for rockfall catchment, should be shown on the contract drawings.

3.3.3 Existing Guide Rail Evaluations and Guide Rail Evaluation Reports

3.3.3.1 Introduction

A Guide Rail Evaluation Report is required during detail design of reconstruction and rehabilitation of provincial highway projects to assist in justifying new barrier system installations, replacements, extensions, or upgrades. Although the report is a detail design deliverable, guide rail review and evaluation, following a process similar to the process described in this section, should be carried out in earlier stages of the project to help determine work related to guide rail (hazard offset and limits, terminal location, grading for guide rail and terminals, shoulder and rounding width, assessment of slope, etc.) and the level of effort/investigation that may be needed at detail design.

The Guide Rail Evaluation Report shall list all existing guide rail types (including concrete barriers, median and roadside if present within the limits of the project), terminal systems, treatments, transitions, energy attenuators, and other roadside safety hardware as applicable (noise barriers, highway closure gates, sign support systems within the DCZ, etc.) by station and length, and list the recommended action (Retain, Extend, Adjust, Remove, Upgrade, Replace) for each installation.

Designers should take into consideration the hazard being protected to determine if an existing system meets the needs. Designers should document any existing roadside hardware that has not been installed in a standard manner and note any associated potential performance concerns.

3.3.3.2 Legacy Systems

In general, legacy systems are existing systems that were crash tested prior to adopting the AASHTO Manual for Assessing Safety Hardware (MASH). Refer to Section 2.4.1 for complete guidance and policy related to roadside safety hardware.

As noted in Section 2.4.1, some non-MASH systems (in particular, systems that met the requirements of NCHRP Report 350) may still be currently offered in the ministry's Contract Preparation System (CPS). A complete list of criteria for current systems is presented below:

1. Typically, current systems meet crash test requirements in the Manual for Assessing Safety Hardware (MASH) of 2009, 2016 or latest. Some systems like SBGR with Channel (a non-MASH system) remain active (June 2023) for some applications like bridge

connections and are expected to be phased out in the near future as MASH-tested alternatives are implemented. Some treatments such as short radius SBGR treatment used on side roads and entrances, for which developing MASH tested alternatives has been difficult, continue to have standard drawings for their non-MASH treatment. Other systems (such as wide energy attenuators) may not have MASH systems equivalents available.

2. Systems described in the RDM represent those for which construction specifications currently exist or will in the near future (standards development is underway). However, it is possible that a new system be introduced that is not described in the current version of the manual.
3. Current systems are those available in the ministry's Contract Preparation System (CPS). If no system is available to afford protection to the traveling public, the Highway Design Office should be consulted to determine if a custom solution that meets project needs can be implemented.

Commonly found legacy guide rail systems include steel beam guide rail, with and without channel, with rail splices located at posts (every second post) and 3 cable guide rail.

3.3.3.3 Evaluation Criteria

Existing installations should be reviewed and evaluated to determine the appropriate recommendation (adjust, extend, remove, upgrade, replace, or retain). The review and evaluation should be carried out using the criteria in the order that they are numbered and described below:

1. System Identification
2. Mounting Height
3. System Condition
4. Operational History
5. Operational and Collision History
6. Limits and Severity of Obstacle or Area of Concern
7. Recommendations and Alternative Treatments

Legacy SBGR on high-speed roads with posted speed of 70 km/h or higher should be upgraded to a MASH TL-3 system or higher as described in this manual. Alternatively, conversion to Type M SBGR may be done if feasible.

Legacy SBGR on low-speed roads may be retained if in good condition in accordance with steps 1 to 7 and with Figure 3-12 Evaluation Process for Legacy SBGR on Low-Speed Roads.

All legacy 3CGR should be replaced with Type M SBGR or with an appropriate roadside barrier system, regardless of posted speed.

Note: Conversion of legacy SBGR to Type M SBGR is a feasible upgrade option if the existing legacy SBGR is mounted on steel posts and a MASH TL-3 system is adequate (most roads, most roadside shoulders). Conversion involves removal and disposal of rail, offset blocks and mounting hardware, adjustment of existing steel posts, and installation of new rail at Type M height and with splices located mid-span between posts as detailed in Figure 4-6.

Step 1, System Identification

As part of system identification, designers should:

- Identify if the existing guide rail system is current or legacy,
- Include a brief description (SBGR mounted on wood posts, SBGR mounted on steel posts, Type M SBGR, 3CGR, etc.),
- Identify the location (station to station) and length,
- Estimate of the system age (less than 15 years, more than 15 years), and
- Identify how the existing system is terminated (terminal type, or transition or treatment, as applicable).

Step 2, Mounting Height

Type M SBGR and other current proprietary systems (EzyGuard 4 SBGR, ACP Sentry SBGR, High Tension Cable Guide Rail systems, etc.): if top of rail (or top cable if a current cable system) heights are (or will be after construction is complete) outside acceptable tolerances as specified in Table 3-3, and if the existing posts and rails (or cables) are currently in acceptable condition, mounting heights shall be adjusted according to applicable standards active in the Contract Preparation System and in accordance with the supplier instructions for proprietary systems.

Legacy SBGR on high-speed highways and CGR (any speed): No need to document existing mounting height as the system will be upgraded (and extended if applicable) if the hazard is still present.

Legacy SBGR on low-speed roads: if top of rail heights are (or will be after construction is complete) outside acceptable tolerances as specified in Table 3-3, and if the existing posts and rails are currently in acceptable condition, mounting heights shall be adjusted according to applicable standards active in the Contract Preparation System. If steel offset blocks are found, they shall be replaced with wooden or plastic offset blocks.

System	Acceptable Mounting Height during Design and During Construction including Seasonal Shutdown – Top of Rail (or Top Cable)	Acceptable Mounting Height at Completion of the Work – Top of Rail
Type M SBGR	710 to 810 mm	760 to 810 mm
Proprietary Systems	As shown on the applicable installation drawing plus or minus 50 mm	As shown on the applicable installation drawing plus or minus 25 mm
SBGR	660 to 760 mm	710 to 760 mm
SBGR with Channel	660 to 785 mm	735 to 785 mm

Notes:

a) Type M SBGR has rail splices located mid-span between posts while legacy SBGR has rail splices located at posts every second post.

b) Minimum height of 660 mm is acceptable for existing non-Type M SBGR systems where posted speed limit is less than 70 km/h and system in good condition.

c) Heights shall be measured vertically at the face of rail. Measurement to top of rail is accurate for existing installations when rail is not partially flattened from snowplows, graders, or minor vehicular impacts.

d) Where SBGR is adjacent to curb, mounting height shall be measured:

i. Vertically at face of guide rail when the face of guide rail is more than 300 mm beyond gutter line.

ii. Vertically at gutter line when face of guide rail is 300 mm or less beyond the gutter line.

Table 3-3: Acceptable Mounting Heights

Step 3, System Condition

For review and evaluation of system condition, barrier installations shall be divided into 100 m long lots, starting at the terminal on the approach end of the installation.

Existing legacy SBGR mounted on steel posts on high-speed roads should only have posts assessed (b and c below) to determine if conversion to Type M is feasible or other upgrade options should be pursued. Break away wood posts are the exception. If the existing system is a legacy system and break-away wood posts are used (mostly on existing short radius treatments but other treatments may also require these posts), designers need to document their existence and condition.

Existing legacy SBGR on low-speed roads should have the condition of all hardware assessed. When more than 50% of the posts and/or rail elements in a lot exhibit the following damage, replacement of the system within a lot is recommended. Where replacement is recommended, a current system available in the ministry's Contract Preparation System should be pursued.

The damage criteria below is only applicable for preparation of Guide Rail Evaluation Reports on capital rehabilitation or reconstruction projects and is not applicable to Maintenance Contracts.

a. Unsound wooden posts (e.g., broken or rotted).
b. Unsound steel posts (e.g., significant corrosion and section loss).
c. Significantly out of plumb wooden or steel posts (e.g., leaning by more than 10° transversely away from roadway: when using a 610mm (24") carpenter level on back of post held vertically, horizontal distance to back of post at bottom of carpenter level exceeds 110mm).
d. Corroded rail elements (e.g., corrosion producing section loss or more than 50% of traffic face of rail is coated in rust).
e. Unsound steel cables on HTCGR systems (frayed at frequent intervals or severely rusted with section loss).
f. Significantly dented rail elements (e.g., rail element is bent or dented with a lateral displacement from traffic face of more than 100mm). Standard depth of new rail element is 83mm in accordance with OPSD 912.125.
g. Significantly flattened rail elements (e.g. rail element height when measured on back of rail has a height greater than 400mm). Standard height of new rail element is 311mm in accordance with OPSD 912.125.

<u>Step 4, Operational History</u>

Review with Maintenance to confirm if there are existing guide rail installations that are exhibiting poor safety performance (e.g., system failures involving vehicle penetrations, vaulting or rollovers) or there are locations involving injury or fatal collisions with roadside obstacles or features. If such locations are identified by Maintenance, a more detailed review and evaluation of the specific location(s) or guide rail installation shall be carried out in accordance with Step 5. If Maintenance identifies locations where guide rail could potentially be removed as the obstacle or hazard has been removed, reconfigured, or relocated, resulting in a severity index being less than the severity index for the existing guide rail, the guide rail should be removed. MTO Severity Index Tables shall be used for evaluation of roadside obstacles, roadside slopes and guide rail systems.

<u>Step 5, Operational and Collision History</u>

A 5-year collision summary from the Accident Information System shall be prepared for the project listing all injury and fatal collisions with existing guide rail installations (including terminals), or roadside obstacles (including rollovers on slopes). This summary shall be reviewed in the field with Traffic and Maintenance in conjunction with the assessment of system condition. The summary shall be included on an Excel file and submitted with the Guide Rail Evaluation Report.

All injury and fatal collisions shall be highlighted in yellow and red respectively. Additional information about injury and fatal collisions (e.g., road alignment, vehicle type, driver condition, weather conditions, guide rail condition, etc.) from Accident Reports and field reviews or investigations shall be included in the Guide Rail Evaluation Report.

<u>Step 6, Limits and Severity of Obstacle or Area of Concern</u>

The limits and severity index of the obstacle or area of concern being shielded shall be reviewed and evaluated to justify continued shielding of the obstacle or area of concern. This information shall be included in the Guide Rail Evaluation Report.

Runout Lengths are provided in Section 2.4.3 for calculation of Length of Need for new guide rail installations, upgrades, replacement, or extensions. MTO Severity Index Tables for evaluation of roadside obstacles, roadside slopes, and guide rail systems are provided in Appendix A.

Length of Need inputs and calculations for new barrier installations and barrier extension installations should be compiled as part of the Guide Rail Evaluation Report. The simplest way to do this is to provide a sketch or part of a plan in letter size (8½" x11") format to show the obstacle or area of concern that was evaluated for each proposed new or extended run of barrier system. Each sheet should include the following information:

- Highway location (preferably station reference);
- Design speed and AADT;
- Lane width, shoulder width, and rounding width;
- Desirable Clear Zone limits;
- Obstacle or area of concern limit lines along with applicable severity indices;
- Barrier system location, length, and configuration;
- Terminal or leaving end treatment length (if applicable);
- Barrier system length of need and encroachment lines (both directions if applicable); and
- For new installations only, expected number of yearly impacts with obstacle or area of concern without barrier vs expected number of yearly impacts with barrier system, along with expected benefit cost result from Roadside.xlsx.

<u>Step 7, Recommendations and Alternative Treatments</u>

The recommended action (Retain, Extend, Adjust, Remove, Upgrade, Replace, New) shall be recorded for each installation. The recommendation should include a construction cost estimate. The estimate should consider removals, installation, and grading (if applicable). Challenges (bodies of water, side road intersections, shallow culverts, utilities, sensitive areas, etc.) should be identified and considered as part of the recommendation.

The options to retain, upgrade, extend and replace existing guide rail systems fall within the scope of highway rehabilitation projects and do not typically require benefit cost analysis.

Where removing obstacles, making them traversable, or installing new guide rail is considered, designers should follow the guidance in the Roadside Evaluation Manual and use Roadside.xlsx to bring forward cost beneficial improvements. Results of the evaluation shall be included in the Guide Rail Evaluation Report. Decisions to carry them forward or defer them will be based on project scope and the merits of these analyses.

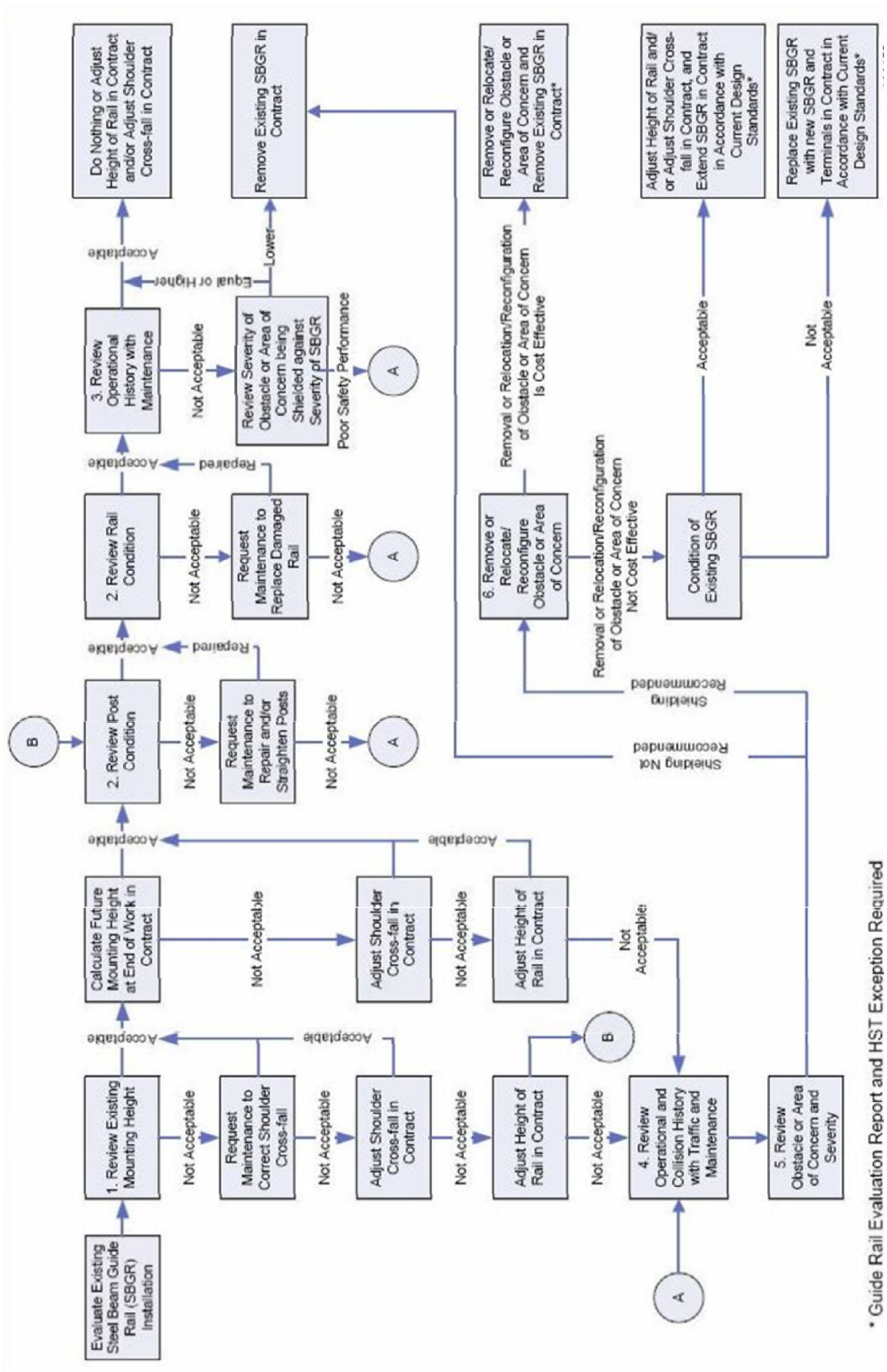


Figure 3-12: Steel Beam Guide Rail Evaluation Process for Rehabilitation and Reconstruction Projects on Low-Speed Roadways

4. Roadside Safety Hardware

As stated in Section 1.0, designers should achieve a balance between competing objectives and constraints when determining how the roadside environment will be configured. The choices made to achieve this balance will be influenced by the:

- Functional classification;
- Design speed;
- Operating speed;
- Posted speed;
- Traffic volumes and composition;
- Drainage considerations;
- Pavement design considerations;
- Right-of-way (ROW) constraints (such as property limits, environmental)
- Other ROW user expectations (such as utility companies);
- Access requirements (such as entrances);
- Constructability considerations;
- Maintenance considerations;
- Funding considerations; and
- Other constraints (such as social, political, technological).

When it has been determined that installation of new roadside safety hardware is justified and cost beneficial for inclusion in a provincial highway project, the hardware specified should meet the safety requirements and criteria specified in this manual and have been implemented in MTO's Contract Preparation System or issued specifically for a project by the appropriate functional office within Highway Standards Branch.

New roadside safety hardware installations, including barriers, terminals, transitions, crash cushions, breakaway sign supports, and frangible base luminaire poles, should meet applicable crash test level acceptance criteria referenced in Section 2.4 and as referenced in each of the following sections for each system. This applies to both permanent systems and temporary systems used in work zones.

The barrier and terminal systems listed in this chapter are complete as of the time of issue of this manual. New systems are often accepted for use on provincial highways between publications of the manual and designers are encouraged to keep informed of the most current version of all standards specifications, special provisions, standard drawings and policy memoranda pertaining to roadside hardware.

Systems shall not be modified from the configurations shown in the standards. Highway Design Office shall be contacted for guidance in case site-specific constraints preclude the use of roadside hardware in its standard configuration.

Existing roadside safety hardware installations on provincial highways providing acceptable in service safety performance and system condition should continue to perform as originally intended until the end of their service life.

4.1 Barrier Systems

Although barrier systems are designed and crash tested to reduce the severity of injuries to occupants in errant passenger vehicles during collisions with roadside obstacles within the roadside environment, dependent on the type of impact, significant vehicle damage can occur along with injury to occupants. Once a barrier system comes into use, the crash is already in progress. The primary purpose of a barrier system is therefore not to prevent a crash, but rather to minimize the severity of the crash.

The severity of the collision with the barrier system should be less than the severity of an impact with a roadside obstacle (e.g. a fixed object or terrain feature) had the barrier not been in place. A barrier system is a device which provides a physical limitation through which an errant vehicle would not normally pass. Barrier systems are designed and crash tested to contain or redirect an errant design vehicle of a particular size range, at a given speed and angle of impact.

Barrier systems are categorized into two major categories based on configuration, function, and location:

- Roadside Barrier – a single sided longitudinal barrier system intended to redirect errant design vehicles from departing the roadway and encroaching into the roadside environment.
- Median Barrier– a double sided longitudinal barrier system used to redirect errant vehicles from crossing a median.

Roadside barrier systems are designed and crash tested to redirect errant vehicles that impact one side of the barrier system from either direction (e.g. bidirectional). They are typically used to shield motorists from natural and man-made obstacles located along either side of the travelled way of highways or ramps. This includes the left side of divided highways with wide medians. Under certain conditions on certain facilities, barriers may also be used to separate high speed vehicular traffic from other facilities such as pedestrian sidewalks, active transportation paths, and snowmobile trails.

A median barrier system is designed and crash tested to redirect errant vehicles that impact either side of the barrier system from either direction within a median. Medians are typically used to separate the travelled ways for traffic in opposing directions, or to separate the travelled ways to manage access (e.g. core-collector systems or service roads).

Temporary barrier systems are designed and crash tested for use in construction work zones to provide physical separation between motorists and certain long term work zone operations. They are typically precast temporary concrete barrier systems or temporary steel barrier systems that are installed on paved surfaces that can be picked up and moved during construction for different construction stages, or steel beam guide rail systems installed temporarily through granular surfaces during construction that can be removed, salvaged, and reinstalled for different construction stages.

4.1.1 Barrier System Types

Barrier systems are further categorized into three system types based on dynamic deflection characteristics and working width requirements:

- Flexible;
- Semi-rigid; and
- Rigid.

Dynamic deflection is the maximum distance that the barrier system is expected to deflect laterally under a specified design impact, measured from the traffic face of the system. Working width is the distance between the traffic face of the system before impact in accordance with a specified crash test and the maximum lateral position of any major part of the system or vehicle after the crash test.

Flexible barrier systems are generally more forgiving than semi-rigid and rigid barrier systems since much of the impact energy is dissipated during deflection of the barrier system. Greater dynamic deflections of flexible barrier systems tend to result in lower impact forces being imposed on the impacting vehicle than with impacts with semi-rigid and rigid barrier systems. In general, flexible barrier systems consist of three or four steel cables mounted on weak steel posts.

Semi-rigid barrier systems are more rigid than flexible barrier systems and more forgiving than rigid barrier systems. In general, these systems consist of steel beams or rails mounted on strong steel posts.

Rigid barrier systems have minimal working widths and either don't deflect or have minimal deflection. In general, these systems are constructed from concrete and are embedded into the pavement surface.

Semi-rigid and flexible barrier systems should only be used if there is a sufficient working width provided between the traffic face of the system and the obstacle beyond the back of the system to accommodate dynamic deflection under the specified design impact. If the barrier system is placed too close to the obstacle, the impacting vehicle can deflect the barrier system into the obstacle, allowing the vehicle to interact with the obstacle.

4.1.2 Barrier System Performance

The performance of barrier systems is dependent on the design, installation, maintenance, and post-impact repair. Associated grading and appropriate terminals, leaving ends, or anchorage requirements, should be provided for each specific barrier system in order for the barrier system to perform as designed and crash tested.

In order to be effective, a barrier system should be capable of restraining a selected design vehicle under specified impact conditions (design vehicle of a particular size range, at a given speed and angle of impact). A barrier system should prevent the selected design vehicle from the following:

- penetrating,
- vaulting over (over-riding), or
- wedging under (under-riding) the installation.

Unless otherwise designed, the barrier system should remain substantially intact so that system elements and debris will not pose an undue risk to occupants in the impacting vehicle or other traffic. The barrier system should be designed and installed to reduce the risk of spearing an impacting vehicle. A vehicle-barrier system collision should result in redirection of the impacting vehicle at a low departure angle that will minimize the risk of interacting with other vehicles. Finally, the collision should not result in excessive lateral or longitudinal deceleration of the vehicle’s occupants.

Barrier systems, whether they are rigid, semi-rigid or flexible, should be of sufficient length and be properly terminated and anchored. In the case of rigid systems, sufficient length, embedment and mass are necessary to prevent the system from being displaced significantly upon impact.

Since the dynamics of a collision are complex, the most effective means of assessing barrier system performance is through full-scale crash testing. By standardizing such tests, barrier system designers can compare the relative safety performance of alternative systems. As noted in the following subsections, MTO has started to implement installations of new roadside safety hardware on provincial highways that meets the crash test and evaluation criteria contained in the AASHTO Manual for Assessing Safety Hardware (MASH (2009 or 2016)). Where roadside safety hardware that meets MASH is currently not available or been implemented by MTO, new roadside hardware installations should continue to meet National Cooperative Highway Research Program Report 350 - Recommended Procedures for the Safety Performance Evaluation of Highway Features (NCHRP Report 350 (1993)).

It is important to highlight that the performance and mechanisms of vehicle containment of barrier systems is not always intuitive. Crash-test and in-service behaviour of barriers and crash cushions can be unpredictable and surprise even those with decades of experience designing, simulating and testing barriers. Nuances and variations in seemingly insignificant components such as offset block height, or the presence or absence of a washer can result in major changes in barrier performance and can mean the difference between successful containment of a vehicle and a catastrophic failure. For this reason, it is imperative that systems be installed in exactly the configuration prescribed in this manual and all applicable standard specifications and drawings and any proposed changes, no matter how minor, be made only in consultation with the Highway Design Office.

4.2 Roadside Barrier Systems

A roadside barrier system is a single sided longitudinal barrier system intended to redirect errant design vehicles from departing the roadway and encroaching into the roadside environment.

The following roadside barrier systems have been implemented for installation as new roadside barrier systems on Provincial Highways:

Flexible Roadside Barrier Systems:

- High Tension Three-Cable Guide Rail (HT3CGR, TL-3)

Semi-Rigid Roadside Barrier Systems:

- Midwest Guardrail System, Type M Steel Beam Guide Rail (W-Beam system, TL-3)
- Australian Construction Products Sentry Guide Rail, ACP Sentry (W-Beam System, TL-3)
- ACP TL-4 (Thrie Beam system, TL-4)
- Ingal Civil Products Ezy-Guard 4 Guide Rail (TL-3)
- Ezy-Guard High Containment (Thrie Beam system, TL-4)
- Guardian 5 Steel Beam Roadside and Median Barriers (TL-5)

Rigid Roadside Barrier Systems:

- Concrete Roadside Barrier (CRB, TL3)

Description and design guidance for each barrier system are described in the applicable sections.

4.2.1 High Tension Three Cable Guide Rail

All MTO contracts advertised after December 31, 2016 that included new or replacement installations of cable guide rail should have specified High Tension Three Cable Guide Rail (HT3CGR) and High Tension Cable Guide Rail Terminal Systems in the contract documents. On MTO contracts advertised prior to December 31, 2016, cable guide rail installations consisted of low tension three cable guide rail systems mounted to wooden posts.

Description:

High Tension Cable Guide Rail (HTCGR) systems are proprietary flexible barrier systems with wire ropes that are pre-tensioned to significantly higher tension values than cables for low tension systems used throughout Ontario since the 1960s. The HTCGR cables are 19 mm diameter, 3 by 7 construction steel wire rope according to AASHTO M 30 with a minimum breaking strength of 173.5 kN, and Type I Class A zinc coating, whereas the low tension system used 12 mm diameter, 7-wire strand steel wire rope according to CAN/CSA G12, grade 800 with a minimum breaking strength of 74 kN and a maximum breaking strength of 100 kN, hot zinc-coated or class A electro-zinc-coated.

At this time, one proprietary system, the Safence HT3CGR system manufactured by Gregory Industries Inc., is currently specified by MTO for shoulder installations and slope installations. This system meets the crash test evaluation acceptance requirements of AASHTO MASH TL-3.

Figure 4-1: Safence HT3CGR Installation

Advantages and Disadvantages:

Advantages of HTCGR installations when compared to semi-rigid and rigid barrier systems are:

- Less visual obstruction;
- Suited for open areas where blowing snow may cause drifting;
- Slope installations can provide increased offset from travelled way on narrow embankments to provide additional clearance for snow plows, oversize loads, and likely fewer vehicular impacts;
- System will continue to function after impacts where several posts have been damaged as tension in system should keep cables at proper mounting heights; and
- More forgiving due to lower deceleration forces sustained by vehicle and occupants during impact.

Disadvantages of HTCGR installations when compared to semi-rigid and rigid barrier systems are:

- Higher dynamic deflection and working width requires larger clear area behind the system;
- Cable tension needs to be monitored;
- No transitions currently available for interconnection with other systems;
- More susceptible to damage from snow plows and minor collisions;
- Impacts into terminal may result in entire system becoming non-functional until repaired' and
- More expensive than low tension cable systems historically used in Ontario

Design Guidance:

HTCGR should be considered when steel beam guiderail cannot provide a minimum offset of 4.25m from the roadway centerline to the face of SBGR on narrow roadways. HTCGR installations should be offset a minimum of 4.25 m from the roadway centerline to provide clearance for snowplowing operations.

HTCGR systems may be installed on the inside and outside of horizontal curves with centerline radii of 250 m or greater.

The recommended minimum length of a HTCGR system is 100 m including terminals, and the maximum recommended installation length is 6,000 m including terminals.

The Safence High Tension Three Cable Guide Rail (HT3CGR) system may be installed at the edge of shoulder as a shoulder installation, or just beyond the shoulder breakpoint as a slope installation. Shoulder installations have the line posts installed at the edge of shoulder in front of the rounding breakpoint, where the breakpoint in rounding is typically 250 mm from the edge of shoulder as part of the 0.5 m wide rounding. Slope installations have the line posts installed up to 200 mm beyond the shoulder breakpoint on foreslopes as steep as 2H:1V. For new construction, new granular base side slopes should be 3H:1V or flatter as specified.

The Safence HT3CGR system uses three 19 mm diameter pre-stretched cables mounted on proprietary direct driven rectangular galvanized steel line posts spaced at 2 m intervals. Each cable is tightened to the manufacturer's specified tension typically ranging from 20 kN to 40 kN dependant upon the temperature of the cable. At 20^0 C, cable tension should be 25.5 kN. At -20^0 C, cable tension should be 37.3 kN.

Turnbuckles are used to achieve the specified tension in the cables according to Contract Documents and manufacturer's instructions. Turnbuckles should be installed at 305 m intervals, and may be located above one another (eg. between same posts).

The reported working width for Safence HT3CGR system is 2.2 m based on MASH-09 TL-3 crash test 3-11 for a slope installation on a 2H:1V slope with a installation length of 172.4 m including terminals. The reported maximum dynamic deflection from crash test 3-11 was 2.0 m.

Modified Safence HT3CGR line posts may be installed over shallow culverts or other buried obstacles with depths of cover ranging from approximately 1.4 m to 0.8 m. This will require the standard 2256 m long line posts to be shortened by up to 0.3 m or up to 0.5 m to reduce embedment depths while reducing line post spacing from standard 2 m spacing to 1.5 m or 1.0 m spacing accordingly.

Length of need for the HT3CGR system starts at post 6 of the terminal system, or 12 m from the terminal anchor assembly.

HTCGR installations should not be installed in front of or behind curbs.

Retroreflective sheeting measuring 125 mm high for line posts should be wrapped around the approach, traffic, and leaving side of line posts between the top and middle cable at maximum intervals of 20 m on tangents. On horizontal curves, spacing of retroreflective sheeting on line posts should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of Safence HT3CGR system installations should be anchored with Safence end terminals as described below.

Figure 4-2: Safence HTCGRT installation

End Treatments and Terminals:

The 12 m long Safence terminals for shoulder installations are flared away from the edge of shoulder over a length of 20 m (including 5 line posts) to provide an offset of 0.6 m from the edge of shoulder to the centre of the terminal anchor assembly to minimize potential for damage from snowplows and impacts by errant vehicles. In vicinity of the terminal, the roadway is widened beyond the edge of shoulder by at least 1.2 m to accommodate the flaring of the terminal and provide a relatively flat area for impacts by errant vehicles.

The 12 m long Safence terminals for slope installations are not flared away from the edge of shoulder. When line posts and terminal posts are installed 0.2 m beyond the shoulder rounding breakpoint, and assuming the width of rounding in front of the breakpoint is 0.25 m, the offset from edge of shoulder to centre of the terminal anchor assembly is 0.45 m to minimize potential for damage from snowplows and impacts by errant vehicles. In vicinity of the terminal, the roadway is widened beyond the centre of the anchor assembly by 0.6 m or at least 1.05 m to provide a relatively flat area for impacts by errant vehicles.

The area immediately downstream of the terminal anchor assembly for shoulder installations and slope installations measuring 23 m x 6 m should be clear and traversable.

Terminals should be delineated with an Object Marker and Snow Plow Marker placed at the edge of shoulder 2 m in advance of an approach end terminal or 2 m beyond a leaving end terminal to minimize potential for damage from snowplows and impacts by errant vehicles. When terminals are impacted by snowplows or errant vehicles, the terminal system is designed to release the cables during impacts, making the entire length of the HT3CGR installation non-functioning until repaired.

Each cable end of the HT3CGR installation is tethered with check cables to the terminal anchor assembly. The purpose of the check cables is to keep released cable ends in proximity to the terminal anchor assembly when released during an impact with the terminal.

Transitions:

There are currently no acceptable transitions available for transitioning and connecting HTCGR to semi-rigid barriers or rigid barrier systems.

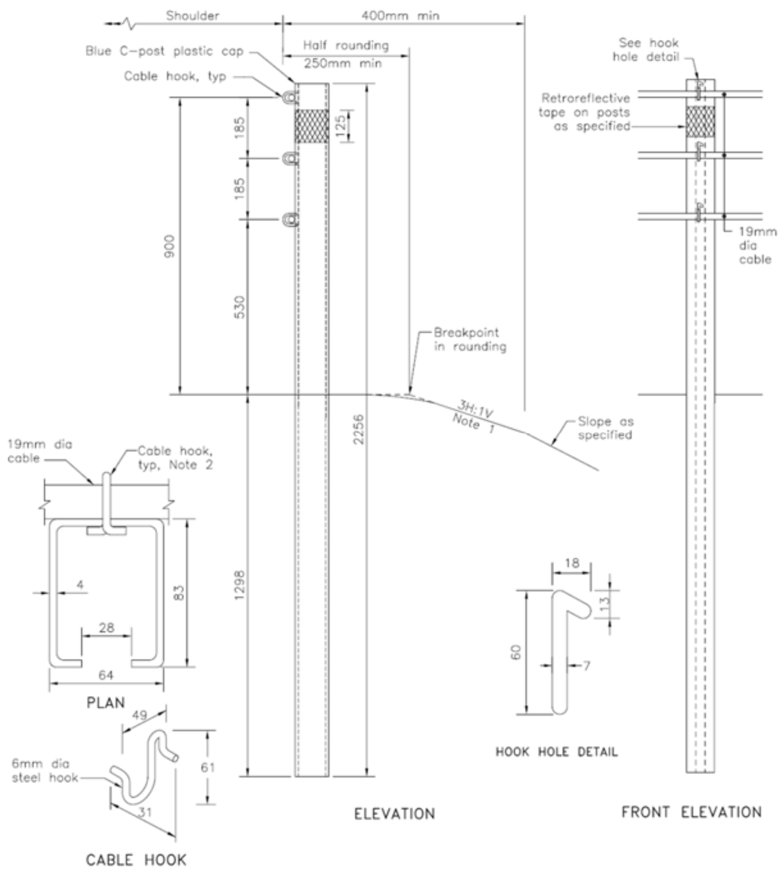


Figure 4-3: Safence HT3CGR Shoulder Installation

See applicable standard for Notes.

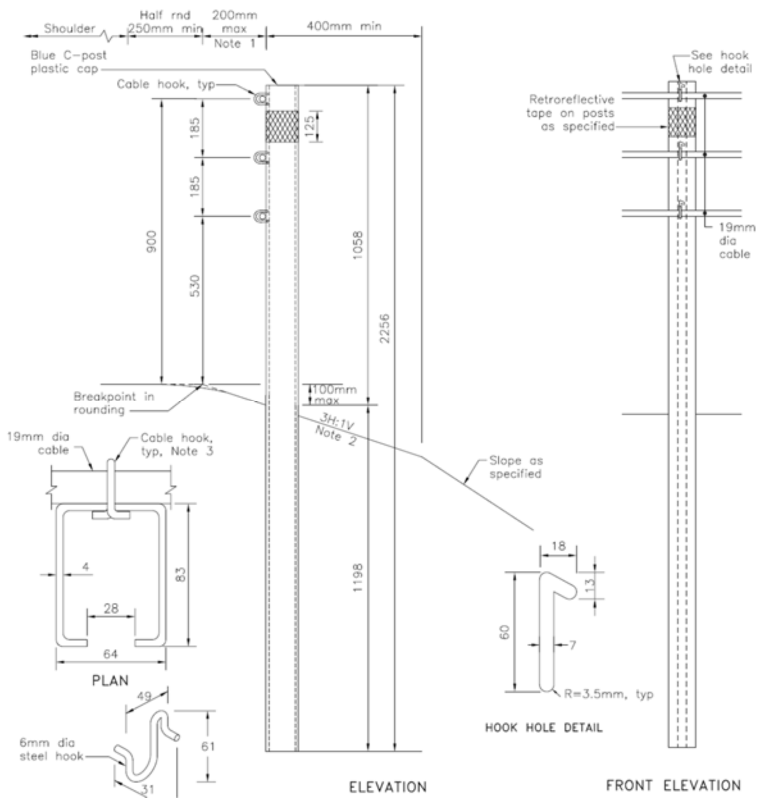


Figure 4-4: Safence HT3CGR Slope Installation

See applicable standard for Notes

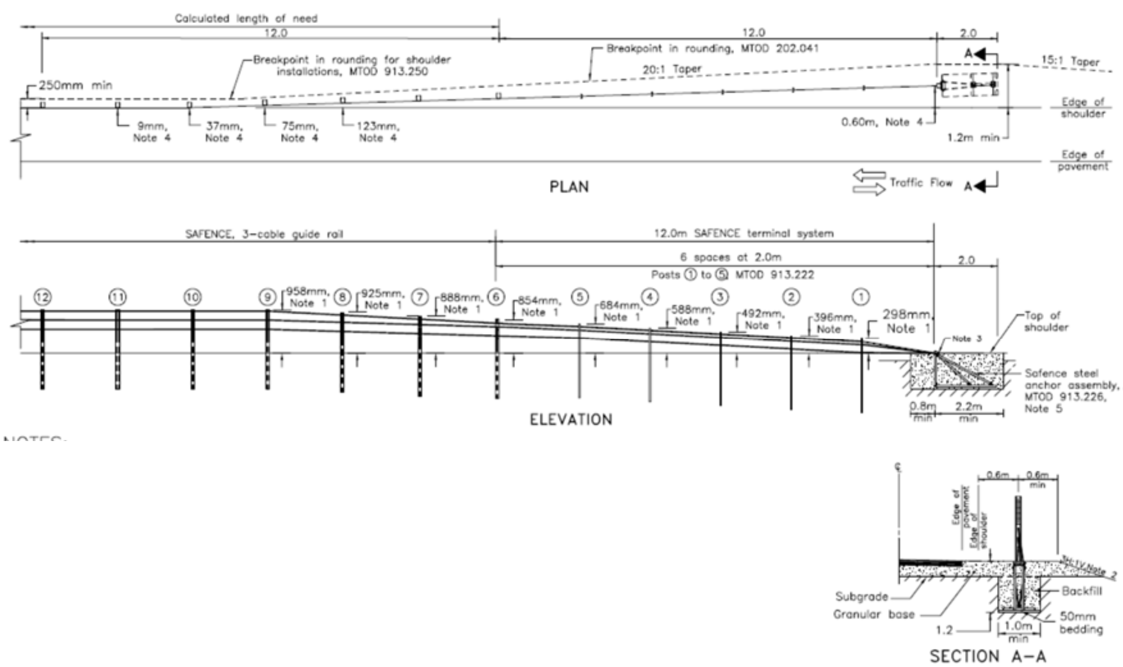


Figure 4-5: Safence HTCGRT Shoulder Installation

See applicable standard for Notes

4.2.2 Steel Beam Guide Rail

All MTO contracts advertised after May 27, 2016 that included new installations of Single Rail Steel Beam Guide Rail should have specified Steel Beam Guide Rail in the contract documents. New installations of Single Rail Steel Beam Guide Rail with Channel should be specified at structure connections only.

4.2.2.1 Midwest Guardrail System

Description

Type M SBGR, which is called Midwest Guardrail System (MGS) in the United States, is a non-proprietary single rail SBGR system that was originally developed and crash tested by the Midwest Roadside Safety Facility (MwRSF) at the University of Nebraska through the Midwest States' Regional Pooled Fund Program. The system was developed to improve performance and capacity of legacy SBGR systems previously installed throughout North America over the past sixty years. The revisions to the legacy SBGR system included a modification to the standard W-beam rail to shift the rail splices away from the posts so that they are now located mid-span between posts as detailed in Figure 4-6. The top of rail was increased from a nominal height of 685 mm to 785 mm. The system continues to use standard 1829mm long W150x13 steel posts spaced at 1.905 m and standard 20 cm deep routed wooden or plastic offset blocks (Type M20 SBGR) or 30 cm deep routed wooden or plastic offset blocks (Type M30 SBGR). Type M SBGR, when installed into cross-section of various configurations described below, meets the crash test acceptance requirements of MASH TL-3.

All legacy SBGR and Type M SBGR systems use a W-beam rail with a height of 311 mm and a nominal thickness of 2.67 mm (12 gauge). The W-beam rails have a nominal length of 3.81 m (total rail length of 4.128 m including overlaps for splices) and are overlapped and spliced together using eight splice bolts at each end. W-beam rails are mounted to the offset blocks and posts using appropriate post bolts specific to the type of offset block and post.

The plastic offset blocks offer several installation advantages over wooden offset blocks and are generally preferred by guide rail installers. Plastic blocks are generally lighter than wooden offset blocks and they have a self-hanging finger that allows the block to be hung on the post rather than held in position while the rail is being mounted. Plastic offset blocks include recycled plastics, and they can also be further recycled into plastic products at the end of their service life. Existing pressure treated wooden offset blocks are prone to splitting and cracking as they age, and when removed at the end of their service life are typically disposed of at landfill sites. Currently, three plastic offset blocks are accepted and specified by MTO for new SBGR installations:

- King Block, manufactured by Trinity Highway Products, LLC;
- Mondo Block, manufactured by Mondo Polymer Technologies; and
- P-Block, manufactured by R. G. Steel Corp.

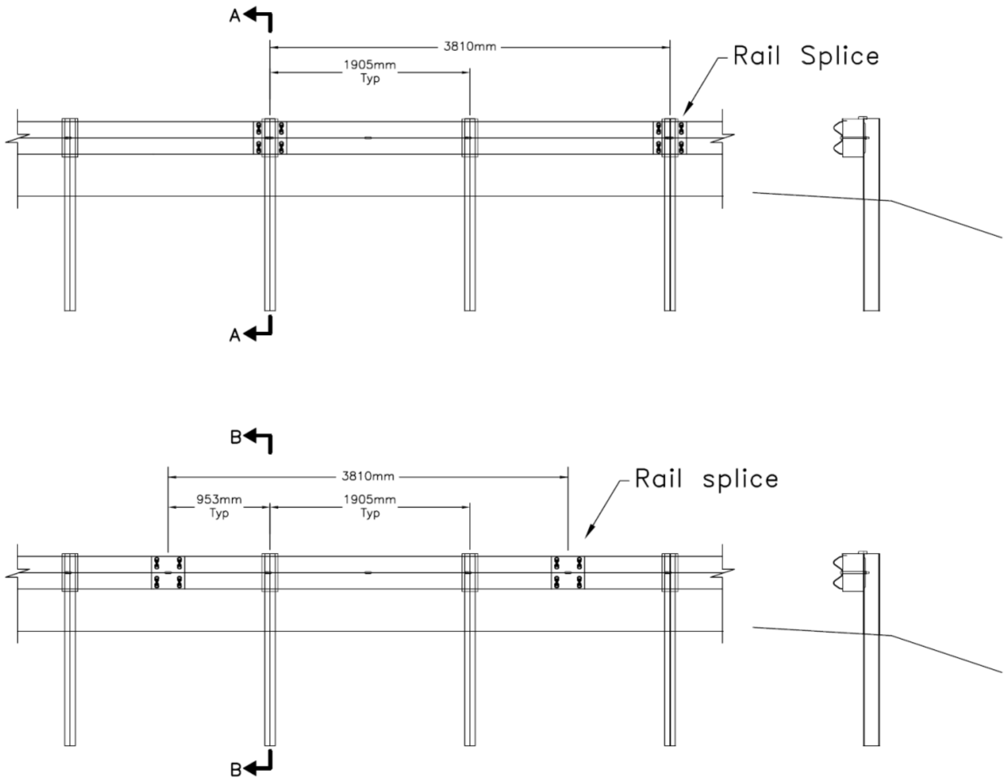


Figure 4-6: Rail Splice Locations on Legacy SBGR vs Type M SBGR

Advantages and Disadvantages:

The main advantages of Type M Steel Beam Guide Rail are:

- Lower maintenance requirements compared to flexible systems;
- Lower dynamic deflection than flexible systems;
- Lower construction cost than rigid systems;
- Can be transitioned and connected directly to structures;
- May be installed at shoulder breakpoints with foreslopes as steep as 2H:1V when installed with longer steel posts; and
- May continue to function after minor impacts prior to repair.

The main disadvantages of Type M Steel Beam Guide Rail are:

- More likely to require to repairs after hits compared to rigid systems;
- Higher dynamic deflection than rigid systems; and
- Higher construction cost than flexible systems.

Design Guidance:

Installations must be offset a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations.

Type M systems may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater. Sharper radius curves require rails to be shop bent at the manufacturer's plant prior to hot dip galvanizing.

The minimum installation length is 25 m including terminals and leaving end treatments, and there is no maximum installation length.

Standard post spacing is 1.905 m, which may be decreased to 0.952 m or 0.476 m to reduce dynamic deflection during impacts. See Table 4.1.

Standard rail mounting height for Type M SBGR measured at face of barrier to top of rail is 785 mm +/- 25 mm. Type M SBGR can accommodate future pavement overlays up to 50 mm in thickness as long as the top of rail is maintained at a minimum height of 710 mm.

Type M20 SBGR should be installed at the edge of shoulder with 1.0 m rounding, where the breakpoint in rounding to a 3H:1V or flatter granular sideslope is a minimum of 500 mm from the edge of shoulder. For additional details see Figure 4-7.

Type M30 SBGR may be installed beyond the edge of shoulder when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1.

Type M30 SBGR may be installed a maximum of 125mm behind barrier curb for TL-3 installations, and a minimum of 1.8 m behind barrier curb with boulevard or sidewalk for TL-2 installations. See Figure 4-7.

Type M20 SBGR with longer 2.438 m long W150x13 steel posts may be installed adjacent to shoulders with the traffic face of post set at the breakpoint in rounding to a 2H:1V or flatter granular sideslope. Erosion of the 2H:1V granular sideslope is a concern which may result in increased maintenance costs and reduced performance of the barrier. This configuration should be used when alternatives are limited. At top of the 2.438 m long post, the number "8" is stamped to signify that the post is 8 feet (2.438 m) long, and when damaged, should be replaced with a 2.438 m long post.

Type M SBGR posts may be installed into solid rock by drilling or breaking out a hole in the rock to allow rotation of the steel posts during impacts. For solid rock within 460 mm of the surface, the diameter of the hole needs to be 530 mm or greater for steel posts. The diameter of the hole below a depth of 460 mm needs to be 254 mm or greater, and advanced to a depth at least 50 mm below bottom of specified post. The front of the hole should align with the traffic face of the post and be backfilled with compacted granular base material.

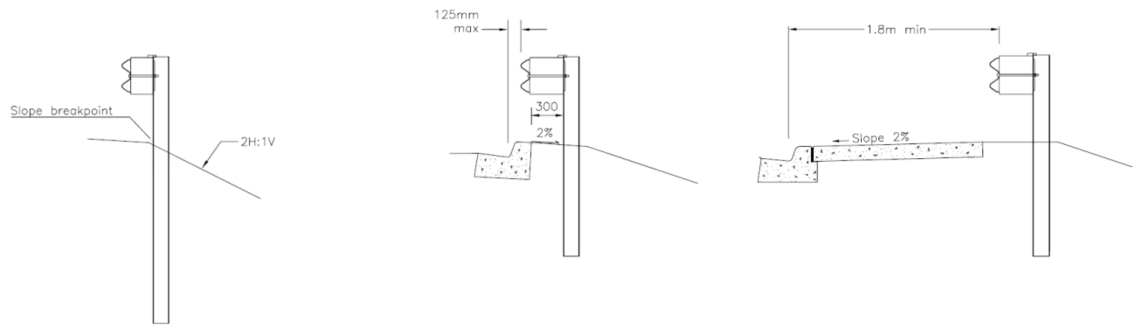


Figure 4-7: Various Type M SBGR Installation Configurations

Type M SBGR systems may be installed through asphalt or concrete by providing leave-outs in the surface to allow for rotation of the steel posts during impacts. Steel posts need to be centered in leave-outs that are at least 381 mm long (parallel to roadway). The traffic face of posts need to be placed 50 mm beyond front edge of leave-outs that are at least 381 mm wide (perpendicular to roadway) to provide at least 177 mm of clearance from back of posts to edge of leave-outs. Leave-outs should extend the full depth of asphalt or concrete pavements, be backfilled with compacted granular base material, and be granular sealed.

Long span Type M SBGR may be installed over shallow culverts or buried obstacles with depths of cover less than 1.2 m and lengths (parallel to roadway) up to approximately 7 m. The modification uses three 145 mm x 195 mm drilled breakaway wooden posts with double 145 mm x 195 mm wooden offset blocks installed on either side of a span without posts 7.62 m long. There is also a version with a span without posts 5.715 m long. The embankment over the length of the treatment shall be widened to provide a minimum platform width of 600 mm behind the posts with a slope of 10H:1V or flatter. No obstacles, headwalls or exposed edges of culvert shall be present within 1.6 m of the traffic face of this treatment to allow for deflection during impacts. On both sides of the 7.62 m span without posts, there needs to be at least 19.05 m of SBGR on the approach side and on the leaving side including terminals. For additional details see Figure 4-8.

Base plated Type M SBGR may be epoxy bolted to the top of shallow concrete box culverts with lengths greater than 7 m (parallel to roadway) with depths of cover ranging from 1.0 m to 0.207 m. When bolting to the top of precast concrete box culverts, a concrete slab at least 200 mm thick and at least 1.2 m wide (measured perpendicular to roadway) should be specified to accommodate the four epoxy anchors. The 23 mm thick steel base plate is welded to the

W150x14 steel post by the manufacturer prior to hot dip galvanizing, and the steel post is cut to length to provide the specified w-beam mounting height.

Transition from Type M SBGR to existing legacy SBGR or existing legacy Steel Beam Energy Attenuators (SBEAT) should take place over a minimum length of 6.6 m.

The cable assembly attaching post 1 of a SBEAT, SBT, or leaving end treatment to the SBGR rail needs to be kept snug to allow tensile forces that develop in the rail during impacts to be transferred to the foundation tube below post 1.

When steel posts are potentially in conflict with a shallow buried utility or drainage pipe, it is acceptable to omit one post in vicinity of conflict. The minimum distance between omitted posts in a SBGR installation is 17.1 m. No modification to the rail is required at the location of an omitted post.

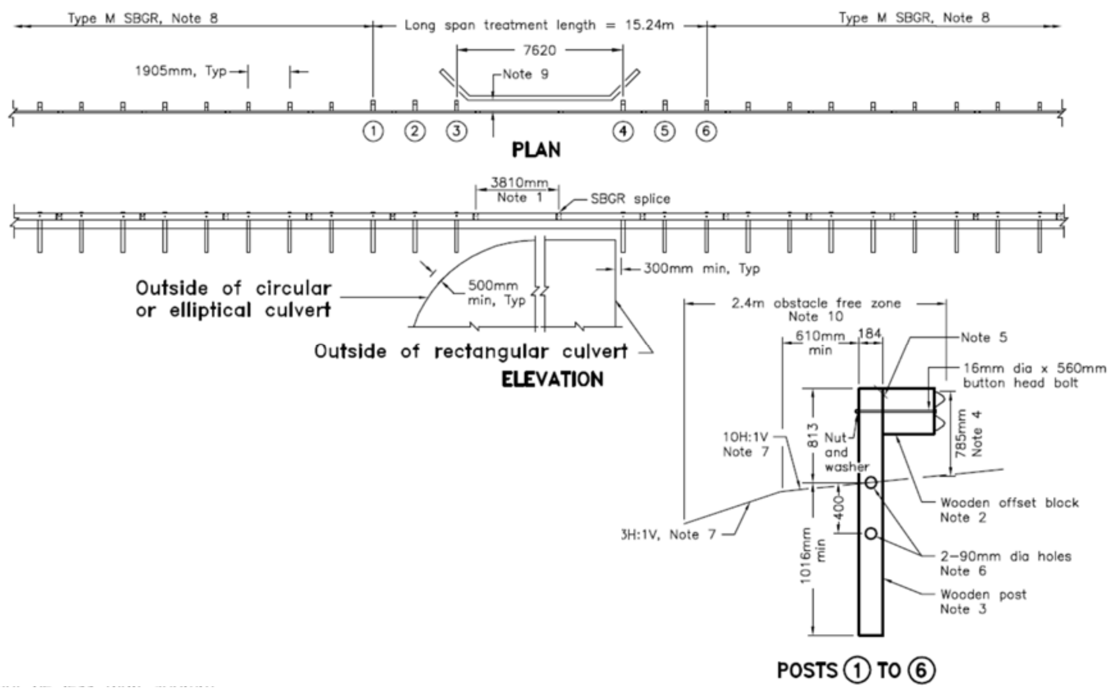


Figure 4-8: Long Span Treatment for Low Fill Culverts
See applicable standard for Notes

Working widths for various configurations and test levels are provided in Table 4-1.

Installation Configuration	**Post Spacing (m)**	**Post Length (m)**	**Working Width MASH-09 (m)**	
			TL-3	**TL-2**
Type M20	1.905	1.829	1.4	1.2
Type M20 adjacent to 2H:1V slope	1.905	2.438	1.4	Note 1
Type M30 adjacent to barrier curb	1.905	1.829	1.3 Note 2	1.0
Type M30 Offset 1.8 m from face of barrier curb	1.905	1.829	Note 3	1.2
Type M20 with ½ post spacing	0.953	1.829	1.0	Note 1
Type M Long Span	7.62	1.829	2.4	Note 1
Type M20 base plated	1.905	Variable	1.3	Note 1

Table 4-1: Working Widths for Type M SBGR Installations

Note 1: Working widths values for this configuration and test level currently not available.

Note 2: Working width based on NCHRP Report 350 crash test 3-11.

Note 3: Configuration not recommended for high-speed roadways with posted speeds of 70 km/h and greater. Configuration meets the crash test acceptance requirements of NCHRP Report 350 TL-2.

Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the Type M steel posts at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of the system installations should be anchored with crashworthy end terminals, leaving end treatments, or transitioned from / to rigid barrier system.

End Treatments and Terminals:

In order to allow development of tensile strength in the SBGR system within the length of need, both ends of the SBGR system installation need to be anchored.

Each end of the SBGR system installation should be anchored by an appropriate end treatment, terminal system, or structure / concrete barrier connection.

A crash worthy terminal system should be installed at the following locations:

- Approach end on divided highways and one-way ramps;
- Approach and leaving end on undivided highways and two-way ramps; and
- Left (median) shoulder on the leaving end on divided highways (eg. divided by a depressed median, median barrier, or median island, and excludes flush medians) when the leaving end is located within the clear zone for opposing traffic.

Crash worthy Steel Beam Energy Attenuator Terminals (SBEAT) currently specified for installations on provincial highway projects are as follows:

- MASH Sequential Kinking Terminal System (MSKT);
- MASH SoftStop Terminal System;
- MASH Max-Tension Terminal System; and
- MASH SPIG Gating End Terminal (SGET)

Crash worthy Steel Beam Terminals (SBT) currently specified for installations on horizontal curves with centreline radii less than 190 m on provincial highway projects are as follows:

- MASH Slotted Rail Terminal (SRT)

- MASH Flared Energy Attenuating Terminal (MFLEAT)

SBEATS should be flared away tangentially from the edge of shoulder over their nominal length of approximately 15 m to provide an offset of 0.3 m from the edge of shoulder to the face of rail at post 1 to minimize potential for damage from snowplows and impacts by errant vehicles.

In vicinity of the approach end of an SBEAT, the roadway is desirably widened beyond the edge of shoulder by at least 1.8 m to accommodate the flaring of the terminal and provide a relatively flat area for impacts by errant vehicles.

In vicinity of the leaving end and constrained approach end of SBEAT, the roadway is widened beyond the edge of shoulder by at least 1.2 m to accommodate the flaring of the terminal and provide a relatively flat area for impacts by errant vehicles.

The area immediately downstream of the first post of an SBEAT or SBT installations measuring 23 m x 6 m should be clear and traversable.

Terminals should be delineated with an Object Marker and Snow Plow Marker placed at the edge of shoulder 2 m in advance of an approach end terminal or 2 m beyond a leaving end terminal to minimize potential for damage from snowplows and impacts by errant vehicles. When terminals are impacted by snowplows or errant vehicles, the terminal system is designed to release the cable assembly attaching post 1 of a terminal to the w-beam rail, potentially reducing the ultimate tensile capacity of the SBGR installation until repaired.

The Type M SBGR Leaving End Treatment (LET) was developed to maintain the tension in the SBGR system on the leaving end of installations where impacts from opposing direction vehicles are not likely to occur. The W-beam rail between Post 1 and Post 2 is anchored by a 25mm diameter cable attachment to a 1.5m deep post anchor tube at Post 1 as shown in Figure 4-9.

The LET is not designed for end-on opposite direction vehicle impacts. The LET should only be installed on divided highways and one-way ramps. The LET should not be installed on undivided highways, as an approach terminal system, or in any location where the LET is located within the clear zone for opposing traffic.

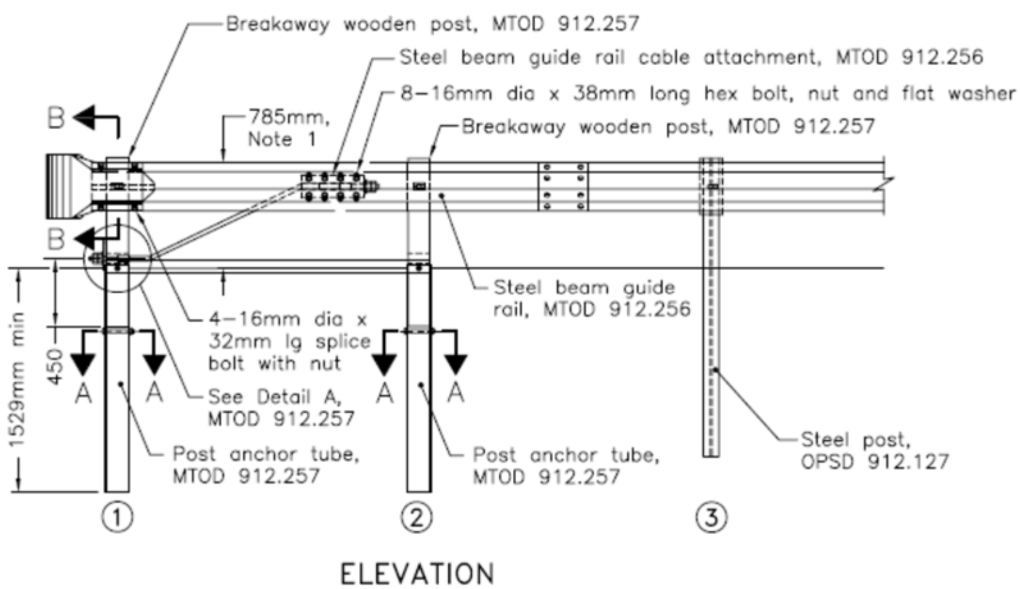


Figure 4-9: Type M20 and M30 SBGR Leaving End Treatment

Openings in Steel Beam Guide Rail

In some cases, it may be desirable to provide a short gap in a run of steel beam guide rail to provide pedestrian access to a property, trail or shoreline. These gaps are often constructed in existing runs of guide rail and typically are terminated with a double “fishtail” end treatment which does not provide adequate anchorage and compromises the functioning of the guiderail for a length of several metres on both sides of the gap.

Where a pedestrian gap is required, a 1 metre gap is available for use. The Pedestrian Access Terminal (PAT) has been crash tested and can be used on a low-speed highways with posted speed 50 km/h or less. It is not recommended for use on high-speed facilities.

Figure 4-10: Pedestrian Access Terminal (PAT) for Steel Beam Guide Rail, courtesy of Northern Infrastructure Products (www.northern-ip.com)

Transitions:

SBGR can be connected directly to rigid barrier systems, as well as to structures, including bridge parapet walls. Rigidity transitions are used to reduce the likelihood of vehicle snagging, pocketing or penetration. Only transitions and connection details active in the Contract Preparation System should be used on the provincial highway system. Figure 4-10 shows the legacy SBGR with channel system connection to a concrete parapet wall.

Rigidity transitions provide a gradual increase in stiffness from semi-rigid SBGR systems to rigid barrier systems or concrete parapet walls through use of decreased post spacing, thicker w-beam materials, nested w-beams (double thickness), thicker thrie beam sections, steel tubes, or steel plates/channels. Transitions should be of sufficient length to accommodate changes in deflection characteristics between semi-rigid and rigid systems. No gaps or discontinuities are permitted between the approach barrier system and the rigid element.

The connection between a semi-rigid SBGR system and a rigid barrier or concrete wall is accomplished by bolting the W-beam shoe, Thrie Beam shoe, and any steel plates that may be part of the transition treatment, to the concrete cross section using anchors or through bolts with steel plates on the back side. Different details can be used for high-speed installations (TL-3) and low speed installations (TL-2) as shown in Figures 4-11, 4-12 and 4-13.

The Long Span Structure Connection (LSSC) shown on Figure 4-11 meets MASH TL-3. It was designed to connect to a vertical face of concrete through nested thrie beams, steel tubes, and a third thrie beam on the field side of the 2.7 m long gap. The advantage of this transition is that it does not require the use of close-spaced posts near the concrete parapet. These posts often conflict with steep slopes and underground installations on bridges.

Other MASH compliant transitions may require the use of nested thrie beams, buttressed end of the concrete parapet wall, steel plates, concrete curbs, and the use of close-spaced posts to provide rigidity transition. Figure 4-12 shows a MASH TL-3 compliant system that consists of nested thrie beams connected to a buttressed concrete shape that can be used both as structure connection and as a concrete barrier to SBGR system.

Both approach and leaving end transitions and connections on undivided highways are the same other than beams are lapped in direction of traffic in the adjacent lane.

The leaving ends of structures and rigid barrier systems on divided highways do not normally require transitions unless required to shield other obstacles or high fill embankments. Where protection is necessary downstream of a rigid system, a rigidity transition should be provided ahead of a semi-rigid system.

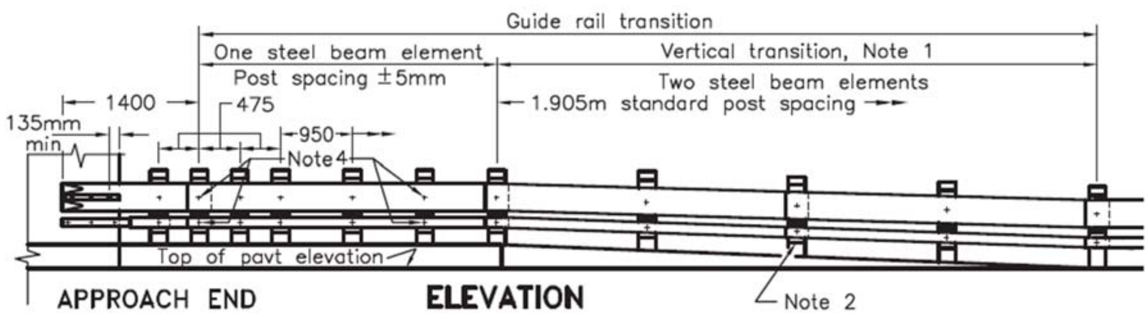


Figure 4-11: Legacy SBGR with Channel Connection to Concrete Parapet Wall, See applicable standard drawing for Notes

Figure 4-12: MASH TL-3 Long-Span Structure Connection (LSSC)

Figure 4-13: MASH TL-3 Thrie Beam Connection to a Buttressed Concrete Wall

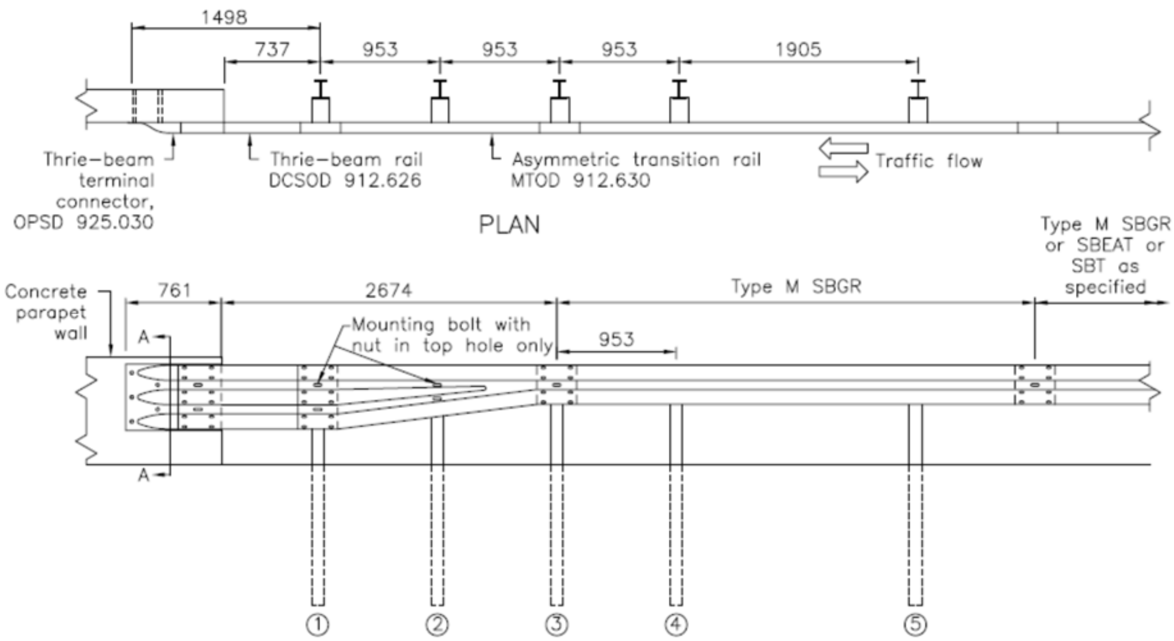


Figure 4-14: MASH TL-2 SBGR Connection to Rigid Barrier on Low Speed Roads

4.2.2.2 Australian Construction Products Sentry Barrier System

Description:

Australian Construction Products (ACP) Sentry Barrier is a proprietary single rail SBGR that was developed and crash tested by Australian Construction Products. The system, when installed into cross-section of various configurations described below, meets the crash test acceptance requirements of MASH TL-3.

ACP Sentry Barrier systems uses the same W-beam rail as Type M with a height of 311 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81m, including the same splicing detail as Type M. Posts are C-shaped steel channels, 72 mm x 115 mm with a specially designed opening to facilitate mounting the rail to the post. Overall system height is 800 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system was crash tested with 4 m nominal length rails, posts every 2 m, and rail splices every second post. The system as specified uses 3.81 m nominal length rails (standard rail length), posts every 1.905 m and rail splices located mid-span between posts. This configuration is functionally equivalent to that which was crash tested.

The system does not make use of offset blocks. The rail is bolted directly to the C-posts using a bolt, nut and proprietary washer.

The MASH TL-3 working width of Sentry SBGR is 1.59m.

Advantages and Disadvantages:

The advantages of ACP Sentry when compared to Type M SBGR are:

- Narrower profile due to absence of offset blocks;
- 2H:1V slope installations can be installed at the breakpoint; and
- Advantageous for use on rehabilitation projects as they allow for shoulder width to be preserved when roadway grade is raised

The disadvantages of ACP Sentry are:

- Treatment options such as long span, reduced post spacing, omitted post and short radius are not currently available;
- Direct connection to rigid barrier not currently available;
- Cannot be installed adjacent to curb and gutter; and
- Higher construction cost

Design Guidance:

Installations must be offset a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations.

ACP Sentry systems may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater. Sharper radius curves require rails to be shop bent at the manufacturer's plant prior to hot dip galvanizing.

The minimum installation length is 30 m including terminals and leaving end treatments, and there is no maximum installation length.

Standard post spacing is 1.905 m. Standard rail mounting height for ACP Sentry measured at face of barrier to top of rail is 800 mm +/- 25 mm.

ACP Sentry SBGR may be installed at the edge of shoulder, where the breakpoint in rounding to a 2H:1V or flatter granular sideslope is a minimum of 250 mm from the edge of shoulder. The rear (non-traffic side) face of the posts may be placed at the breakpoint of a slope as steep as 2H:1V when longer posts are used.

ACP Sentry SBGR may be installed beyond the edge of shoulder when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1.

ACP Sentry posts may be installed into solid rock by drilling or breaking out a hole in the rock to allow rotation of the steel posts during impacts. Post length may also be shortened depending on the depth of the rock beneath the surface. Installation in asphalt or concrete is not permitted.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the sides of the steel C-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

End Treatments and Terminals:

Approach and leaving ends of the system installations should be anchored with crashworthy end terminals or leaving end treatments as applicable. A transition to rigid barrier system is not available. Transition to a legacy SBGR system with rail splices every second post requires the use of the 2858 mm transition rail detail used to transition the Type M SBGR. Sentry SBGR may also be installed adjacent to Type M SBGR as the two systems have rail splices located mid-span between posts.

Figure 4-14 illustrates the advantage in placing a proprietary blockless SBGR system adjacent to slopes of 3H:1V and 2H:1V slope compared to SBGR M20.

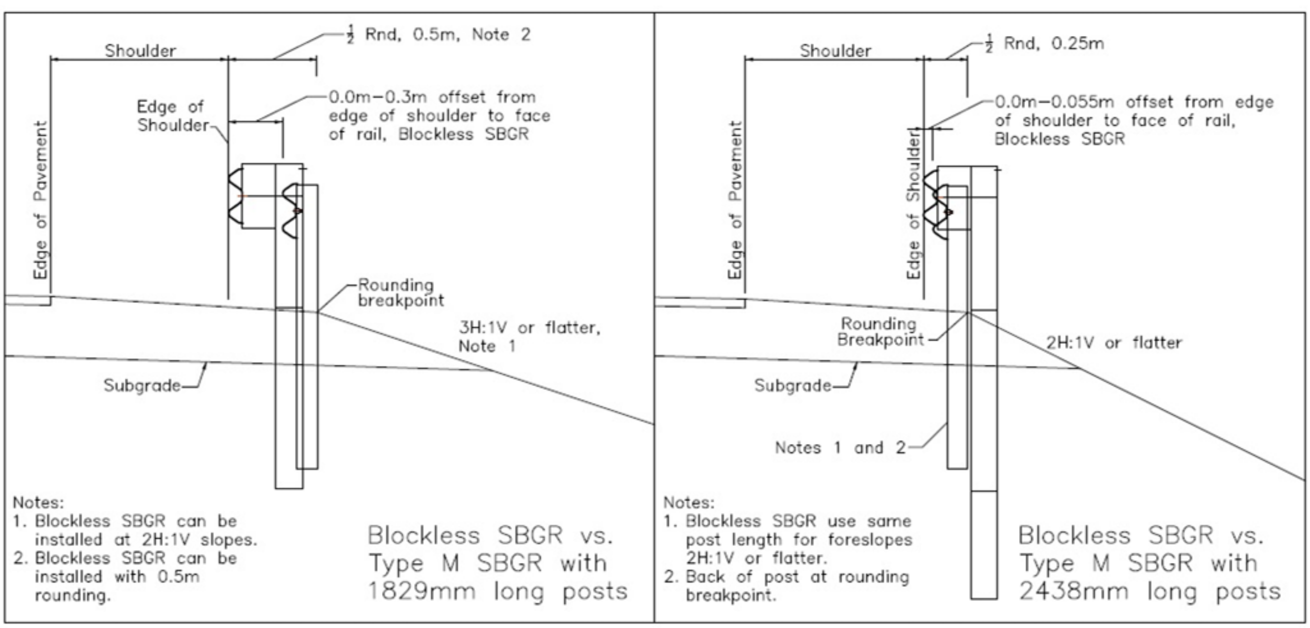


Figure 4-15: Blockless SBGR Compared to M20 SBGR at Rounding Breakpoint

4.2.2.3 Ingal Civil Products Ezy-Guard 4 Guide Rail

Description

Ingal Civil Products Ezy-Guard 4 Guide Rail is a proprietary single rail SBGR that was developed and crash tested by Ingal Civil Products. The system, when installed into cross-section of various configurations described below, meets the crash test acceptance requirements of MASH TL-3 and NCHRP Report 350 TL-4.

The as-implemented Ezy-Guard 4 system uses the same W-beam rail as Type M with a height of 311 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81m, including the same splicing detail as Type M. Posts are Z-shaped hot rolled flat steel, 50 mm x 90 mm with specially designed resistance and positioning tabs to facilitate mounting the rail to the post. Overall system height is 787 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system was crash tested with 4 m nominal length rails, posts every 2 m, and rail splices every second post. The system as specified uses 3.81 m nominal length rails with posts every 1.905 m and rail splices located mid-span between posts. This configuration is functionally equivalent to that which was crash tested.

The system does not make use of offset blocks. The rail is attached to the Z-posts using a proprietary Carriage Assembly and bolt.

The MASH TL-3 working width of Ezy-Guard 4 SBGR is 1.65 m. When installed at the breakpoint of a 2H:1V slope, the working width is 1.95 m.

Figure 4-16: Ingal Civil Ezy Guard 4 System

Advantages and Disadvantages:

The advantages of Ezy-Guard 4, when compared to Type M SBGR, are:

- Narrower profile due to absence of offset blocks;
- 2H:1V slope installations can be installed at the breakpoint; and
- Advantageous for use on rehabilitation projects as they allow for shoulder width to be preserved when roadway grade is raised.

The disadvantages of Ezy-Guard 4 are:

- Treatment options such as long span, reduced post spacing, omitted post and entrances are not currently available;
- Direct connection to rigid barrier not currently available;
- Cannot be installed adjacent to curb and gutter; and
- Higher construction cost

Design Guidance:

Installations must be offset a minimum of 4.25 m from the roadway centerline, to provide clearance for snowplowing operations.

Ezy-Guard 4 systems may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater. Sharper radius curves require rails to be shop bent at the manufacturer’s plant prior to hot dip galvanizing.

The minimum installation length is 20 m not including terminals and leaving end treatments, and there is no maximum installation length.

Standard post spacing is 1.905 m. Standard rail mounting height for Ezy-Guard 4 measured at face of barrier to top of rail is 787 mm +/- 25 mm.

Ezy-Guard 4 SBGR may be installed at the edge of shoulder, where the breakpoint in rounding to a 2H:1V or flatter granular side slope is a minimum of 250 mm from the edge of shoulder, or with the rear (non-traffic side) face of the posts right at the rounding breakpoint.

Ezy-Guard 4 SBGR may be installed beyond the edge of shoulder when the surface is 10H:1V or flatter and may be installed with a flare rate up to 10:1.

Ezy-Guard 4 steel Z-posts may be installed into solid rock by drilling or breaking out a 110 – 300 mm hole. The specifically engineered steel Z-post dissipates energy by yielding through bending near ground level. Because of this, a cut out for post rotation is not necessary. Post length may also be shortened depending on the depth of the rock beneath the surface.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the steel Z-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

End Treatments and Terminals:

Approach and leaving ends of the system installations should be anchored with crashworthy end terminals or leaving end treatments as applicable. A transition to rigid barrier system is not available. Transition to a legacy SBGR system with rail splices every second post requires the use of the 2858 mm transition rail detail used to transition the Type M SBGR. Ezy-Guard 4 SBGR may also be installed adjacent to Type M SBGR as the two systems have rail splices located mid-span between posts.

4.2.3 Concrete Roadside Barrier

All MTO contracts advertised after December 31, 2017 that included new installations of Concrete Roadside Barrier installed on the roadside (e.g. not in a median embedded into asphalt on both sides) should have specified Concrete Roadside Barrier in the contract documents.

Description:

Concrete Roadside Barrier (CRB) is a rigid barrier system designed to redirect vehicles through resistance of lateral forces. Generally, rigid barrier systems differ from other barrier systems since they are not designed to yield upon vehicle impact and they do not deflect significantly.

There are various shapes of concrete barriers used throughout North America such as New Jersey shape, F-shape, and constant slope to name a few. In Ontario, the modified New Jersey shape concrete barrier has been used on provincial highways since the early 1990s which has the hinge point between the lower 55^0 sloped portion of the wall and the upper 1H:10V sloped portion of wall set at a height of 250 mm above the pavement, similar to the F-shape concrete barrier. The original New Jersey shape concrete barrier has the hinge point set at a height of 330 mm above the pavement. The New Jersey shape and F-shape concrete barriers also include a bottom vertical section projecting 75 mm above the asphalt pavement whereas the modified New Jersey concrete barrier used in Ontario does not have the bottom vertical face project above the top of pavement.

F-shape and New Jersey shape median concrete barriers with a minimum height of 810mm (32”) meet the crash test acceptance requirements of MASH TL-3 when embedded into asphalt pavement on both sides of the barrier.

For roadside installations of CRB without being embedded into asphalt pavement on the back side of the barrier, steel reinforcement and additional embedment depths into granular base are required in order to meet the crash test acceptance requirements of MASH TL-3. Details for installation of both cast-in-place design and pre-cast CRB are provided in Figure 4-15.

Advantages and Disadvantages:

The advantages of CRB when compared to flexible and semi-rigid systems are:

- Lower routine maintenance requirements;
- Minimal dynamic deflection;
- Can be used to shield embankments with a foreslope ratio as steep as 1.5H:1V;
- Can be directly connected to structures; and

- System continues to function properly after most impacts, without any repair required.

The disadvantages of CRB are:

- Limited flexibility to accommodate future pavement overlays while maintaining current test level performance level;
- Does not permit overland drainage flow;
- Storm sewer system is required in most situations;
- Higher repair costs after severe impacts that exceed the performance crash test level; and
- Higher construction costs.

Design Guidance:

Cast-in place CRB may be installed on the inside and outside of horizontal curves with centerline radii of 45 m or greater.

Pre-cast CRB may be installed on the inside and outside of horizontal curves with centerline radii of 90 m or greater. For installations on horizontal curves, the squared ends of each precast unit need to be beveled when cast based on the radii of the curve to provide a good connection with the adjacent pre-cast units.

The minimum installation length is 30 m, and there is no maximum installation length.

Offset from edge of travelled lane should not exceed 4.0 m.

Continuous fully paved surfaces need to be provided between the edge of travelled way and traffic face of CRB with cross-fall not exceeding 10%.

Curbs should not be located between the edge of travelled way and traffic face of CRB.

The CRB design requires a 255 mm embedment into the compacted granular base for additional stability and mass to counteract overturning and sliding. On the backside of CRB, the top of compacted granular base should slope downward at 6% for at least 610 mm to the breakpoint to the 1.5H:1V or flatter granular sideslope. The 1.5H:1V configuration was taken to be the worst case installation scenario during crash testing, and a slope of 2H:1V or flatter is recommended to address erosion concerns. Granular sealing should be provided on granular base for a width of at least 1 m beyond back of CRB.

Precast CRB is fabricated in 4m or 6 m long units. The units are interconnected using a rebar grid that is placed in an open slot that is cast into each end of the CRB unit.

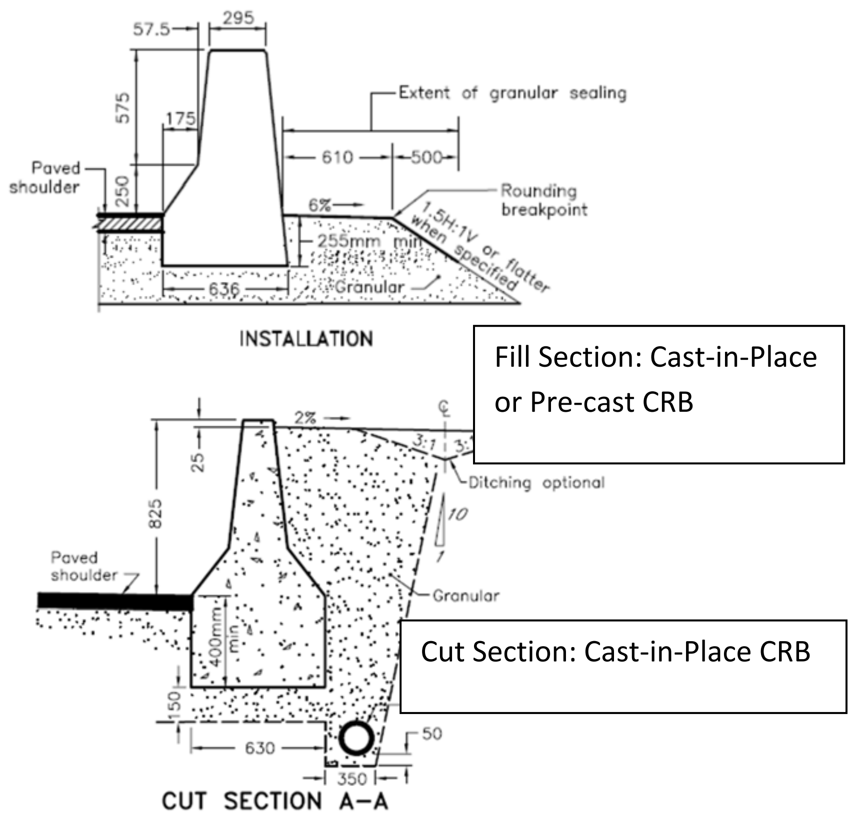


Figure 4-17: Concrete Roadside Barrier Installations

Following insertion of the rebar grid into the slot, non-shrink grout is placed in the slot to complete the connection.

CRB should not be used in locations where relief flow from an overland flow route will cross the roadway during flood events.

A minimum offset between the toe of the traffic face of the CRB and the face of an obstacle located behind the CRB should be at least 0.8 m to account for potential shifting of CRB during MASH TL-3 impacts (Dynamic deflection of 142 mm reported for pre-cast design).

Approach and leaving ends of the system installations should be shielded with an appropriate end treatment or transitioned to / from another roadside barrier system.

CRB is cost effective on high volume, high-speed roadways where there is a high frequency of collisions since maintenance and repair of CRB after most impacts is minimal when compared to semi-rigid and flexible systems. CRB may be preferable in locations where the system will be installed close to the traveled way, where site access is limited, and/or where lane closures for repairs would be costly and disruptive.

CRB performs all of the drainage functions of a curb and gutter system, and edge of catch basin grates should be offset 125 mm from toe of CRB.

For cut-installations, only cast-in-place CRB option is currently available as shown in Figure 4-15.

End Treatments:

The blunt end or tapered down end of any rigid barrier system is a hazard if it is located where it may be hit by an errant vehicle. Each end of the CRB system, when not transitioned to another barrier system should shielded with a single sided energy attenuator at the following locations:

- Approach end on divided highways and one-way ramps;
- Approach and leaving end on undivided highways and two-way ramps; and
- Left (median) shoulder on the leaving end on divided highways when the leaving end is located within the clear zone for opposing traffic.

Acceptable single sided attenuators that meet the crash test acceptance requirements of NCHRP Report 350, TL-3 are as follows:

- Box Beam Bursting Energy Attenuating Terminal (BB-BEAT)
- QuadTrend

Additional details for each system are provided in Section 4.4.

Transitions:

CRB can be connected to semi-rigid barrier systems and other rigid barrier systems including concrete bridge rails.

The standard transition and connection details for CRB connections to semi-rigid barriers are described in Section 4.2.

Standard transitions provide a gradual increase in stiffness from the SBGR system to the CRB. The standard transition should be of sufficient length to accommodate changes in deflection characteristics, shape and height, between the two systems. No gaps or discontinuities are permitted between the approach SBGR and CRB.

4.2.4 Thrie Beam Systems

Thrie beam roadside barriers provide a higher performing alternative to a traditional W-beam system. A thrie beam rail resembles a W-beam rail however it has three ridges and two valleys compared to the two ridges and one valley of a W-beam. A standard thrie beam rail is the same 4,128 mm length as a standard W-beam rail and has a height of 508 mm compared to the 311 mm height of W beam.

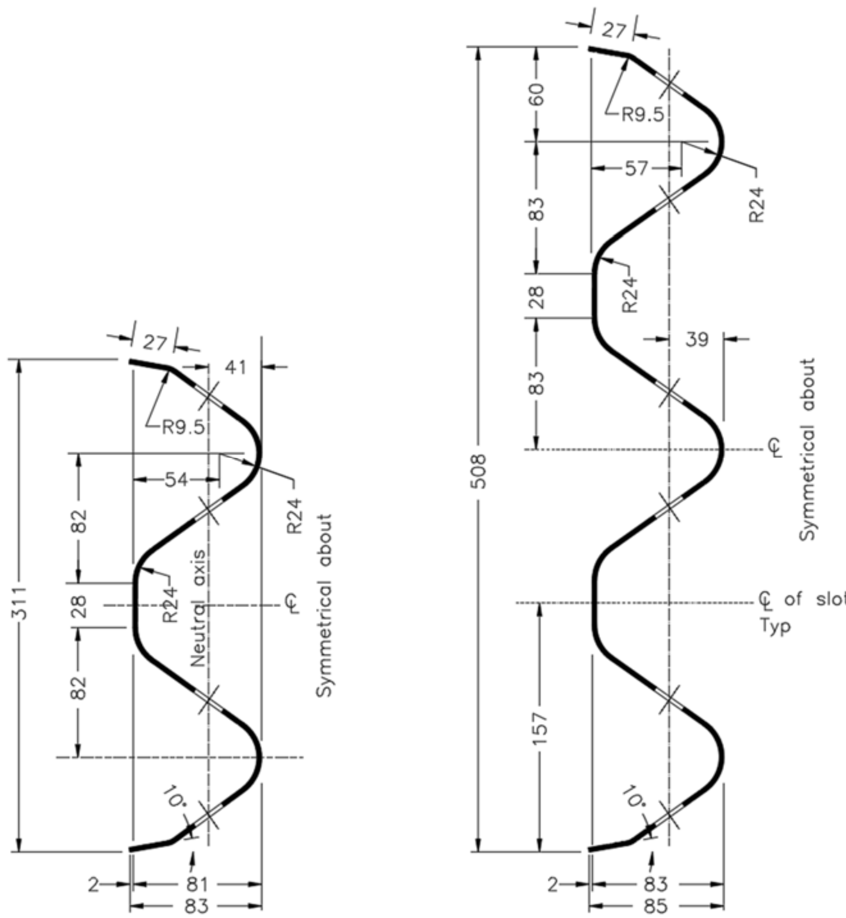


Figure 4-18: W-Beam and Thrie Beam Cross Section Comparison

The thrie beam roadside barrier systems implemented for use on provincial highways should be crash tested to MASH Test Level 4 and thus provide superior performance compared to their TL-3-only thrie beam and W beam counterparts. MASH Test Level 4 systems can contain and redirect a 10,000 kg single-unit truck at an impact angle of 15 degrees and a speed of 90 km/h, in addition to meeting the Test Level 3 requirements. They are not intended to redirect tractor-semitrailers as Test Level 5 barriers are capable of, however, they may provide some enhanced capabilities in partially containing such vehicles in less severe impacts. The disadvantage of these systems is the higher installation cost compared to TL-3 SBGR systems. However, this may be partially offset by reduced maintenance costs as these systems are less likely to be significantly damaged in minor impacts with lighter vehicles compared to TL-3 SBGR systems.

Thrie beam roadside barriers should be considered at high-collision locations on roads with commercial traffic volumes in excess of 7,000 vehicles per day.

Approach and leaving ends of thrie beam system installations must be transitioned to a TL-3 W-beam system before being terminated with an appropriate terminal or end treatment. Transitions should be constructed beyond the calculated length of need where TL-4 barrier required to shield an area of concern.

4.2.4.1 Australian Construction Products TL-4 Barrier

Description

ACP TL-4 barrier is a proprietary single rail thrie beam barrier that was developed and crash tested by Australian Construction Products. The system when installed in a roadside configuration meets the crash test acceptance requirements of MASH TL-3 and TL-4.

ACP TL-4 Barrier uses a standard thrie beam rail with a height of 506 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81m, with a standard splicing detail. Posts are C-shaped steel channels, 72 mm x 115 mm and 2,000 mm in length with a specially designed opening to facilitate mounting the rail to the post. Overall system height is 1,050 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system width is 200 mm. Rail splices are located at every other post. The system has not been crash tested with splices located mid-span between posts.

The system does not make use of offset blocks. The rail is bolted directly to the C-posts using a bolt, nut, and proprietary washer.

ACP TL-4 SBGR should be installed at the edge of shoulder with 1.0 m rounding, where the breakpoint in rounding to a 3H:1V or flatter granular sideslope is a minimum of 500 mm from the edge of shoulder. The minimum distance from the rear face of the post to the rounding breakpoint is 400 mm when TL-3 performance is required and 1,530 mm when TL-4 performance is required.

Figure 4-19: ACP TL-4 Barrier

The MASH TL-3 working width of the ACP TL-4 barrier is 1.45m. The MASH TL-4 working width is 1.53 m.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the sides of the steel C-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

4.2.4.2 Ezy Guard High Containment Barrier

Description

The Ezy Guard High Containment barrier is a proprietary single rail thrie beam barrier that was developed and crash tested by Ingal Civil Products of Australia. The system when installed in a roadside configuration meets the crash test acceptance requirements of MASH TL-3 and TL-4.

The Ezy Guard High Containment barrier uses a standard thrie beam rail with a height of 506 mm, a nominal thickness of 2.67 mm (12 gauge) and a length of 3.81m, with a standard splicing detail. Posts are hot-rolled flat steel Z-shapes with specially designed resistance and positioning tabs to facilitate mounting the rail to the post, 140 mm x 60 mm and 2,000 in length. Overall system height is 980 mm to the top of the rail with the top of the posts being 10 mm lower than the top of the rail. The system width is 248 mm. Rail splices are located at every other post. The system has not been crash tested with splices located mid-span between posts.

The system does not make use of offset blocks. The rail is attached to the Z-posts using a proprietary Carriage Assembly and bolt.

Ezy Guard High Containment should be installed at the edge of shoulder with 1.0 m rounding, where the breakpoint in rounding to a 3H:1V or flatter granular sideslope is a minimum of 500 mm from the edge of shoulder. The minimum distance from the rear face of the post to the rounding breakpoint is 1,770 mm.

The MASH TL-3 working width of the Ezy Guard High Containment barrier is 1.16 m. The MASH TL-4 working width is 2.46 m.

Reflectors with a minimum reflective surface of 100 x 100 mm are attached to the sides of the steel Z-posts perpendicular to traffic at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Figure 4-20: Ezy Guard High Containment Barrier

4.3 Median Barrier Systems

A median barrier system is designed to redirect vehicles that may impact either side of the barrier system. The primary purpose of a median barrier system is to reduce the potential for and severity of cross-median collisions. Medians are typically used to separate the travelled ways for traffic in opposing directions, or to separate the travelled ways to manage access (e.g. core-collector systems or service roads).

The following median barrier systems have been implemented for installation as new median barrier systems on Provincial Highways:

Flexible Median Barrier Systems:

- High Tension Four-Cable Median Guide Rail (HT4CMGR)

Semi-Rigid Median Barrier Systems:

- Type M Double Rail Steel Beam Guide Rail (Type M SBGR)
- Australian Construction Products Sentry Median Guide Rail
- Ingal Civil Products Ezy-Guard 4 Median Guide Rail
- Guardian 5 Steel Beam Median Barrier

Rigid Median Barrier Systems:

- Type M Median Concrete Barrier (Type M MCB)
- Type TW Median Concrete barrier (Type TW MCB)

Description and design guidance for each barrier system are described in the applicable sections.

4.3.1 High Tension Four Cable Median Guide Rail Systems

Description:

High Tension 4-Cable Median Guide Rail (HT4CMGR) systems are proprietary flexible barrier systems with wire ropes that are pre-tensioned to significantly higher tension values than cables for low tension systems used throughout Ontario since the 1960s. The HTCGR cables are 19 mm diameter, 3 by 7 construction steel wire rope according to AASHTO M 30 with a minimum breaking strength of 173.5 kN, and Type I Class A zinc coating.

HT4CMGR has been installed on Highway 401 between London and Tilbury to mitigate cross-median collisions. Two systems are currently available which have met the crash test acceptance requirements of NCHRP Report 350 and MASH-09 TL-3 and will be further crash tested in accordance with the updated requirements of MASH-16. The systems are the Gregory Safence 4-Cable and Trinity CASS S3 4-Cable.

Advantages and Disadvantages:

Advantages of HT4CMGR installations when compared to semi-rigid and rigid barrier systems are:

- Lower supply and installation costs;
- Less visual obstruction;
- Suited for open areas where blowing snow may cause drifting;
- Can be installed within wide depressed medians ranging in width from 10.5 m (assuming 1.0 m wide median shoulders) to over 23 m with 4H:1V or flatter slopes. Semi-rigid and rigid systems have to be installed adjacent to median shoulders and can’t be installed on 4H:1V or 6H:1V median slopes common in Ontario.
- Installations within medians provide increased offset from one or both travelled ways compared to installations immediately adjacent to median shoulders, likely resulting in significantly fewer vehicular impacts;
- System will continue to function after impacts where several posts have been damaged as tension in system should keep cables at proper mounting heights; and
- More forgiving due to lower deceleration forces sustained by vehicle and occupants during impact.

Disadvantages of HTCGR installations when compared to semi-rigid and rigid barrier systems are:

- Higher dynamic deflection and working width requires larger clear area behind the system;
- Cable tension needs to be monitored;

- No transitions currently available for interconnection with other systems;
- More susceptible to damage from minor collisions; and
- Impacts into terminal may result in entire system becoming non-functional until repaired.

Design Guidance:

HT4CMGR installations in medians with 4H:1V slopes should be offset a maximum of 1.2 m from one of the shoulder rounding breakpoints, and a minimum of 2.5 m from the toe of the 4H:1V slope. Based on this configuration with 1.0 m wide median shoulders and 1.0 m wide roundings, minimum median width is 10.32 m. See Figure 4-19 for details.

HT4CMGR installations in medians with 6H:1V slopes should be offset a minimum of 2.5 m from the toe of one of the 6H:1V slopes, and no offset requirements from either shoulder rounding breakpoint. Therefore minimum median width would be similar to the 4H:1V median described above, and wider medians would allow placement of the system further away from one of the shoulder rounding breakpoints to further reduce probability of impacts.

HT4CMGR may also be installed in medians with 4H:1V slopes on one side, and 6H:1V slopes on opposite side using guidance from above for determining optimum location of system on either slope.

HT4CMGR may also be installed in medians with 4H:1V or flatter slopes with flat bottom ditches using guidance from above for determining location of system from toe of either slope

HT4CMGR systems may be installed on the inside and outside of horizontal curves with centerline radii of 400 m or greater. On rural freeways, minimum horizontal curve radii are typically larger than 650 m, with many freeways in Ontario having horizontal curves of 1745 m (1 degree) or flatter.

For installations on horizontal right curves, the HT4CMGR system should be installed on the left side of the median ditch. For installations on horizontal left curves, the HT4CMGR system should be installed on the right side of the median ditch.

The recommended minimum length of a HTCGR system is 100 m including terminals, and the maximum proposed installation length is currently 6,000 m including terminals. Successful installations longer than 6,000 m are reported by several manufacturers.

Each HT4CMGR system uses four 19 mm diameter pre-stretched cables mounted within and/or attached to face of proprietary galvanized steel line posts with various foundation options spaced at intervals ranging from 2 m to 5 m, dependent on desired working width required.

Each cable is tightened to the manufacturer's specified tension typically ranging from 20 kN to 40 kN dependant upon the temperature of the cable. At 20^0 C, cable tension should be 13.7 kN.

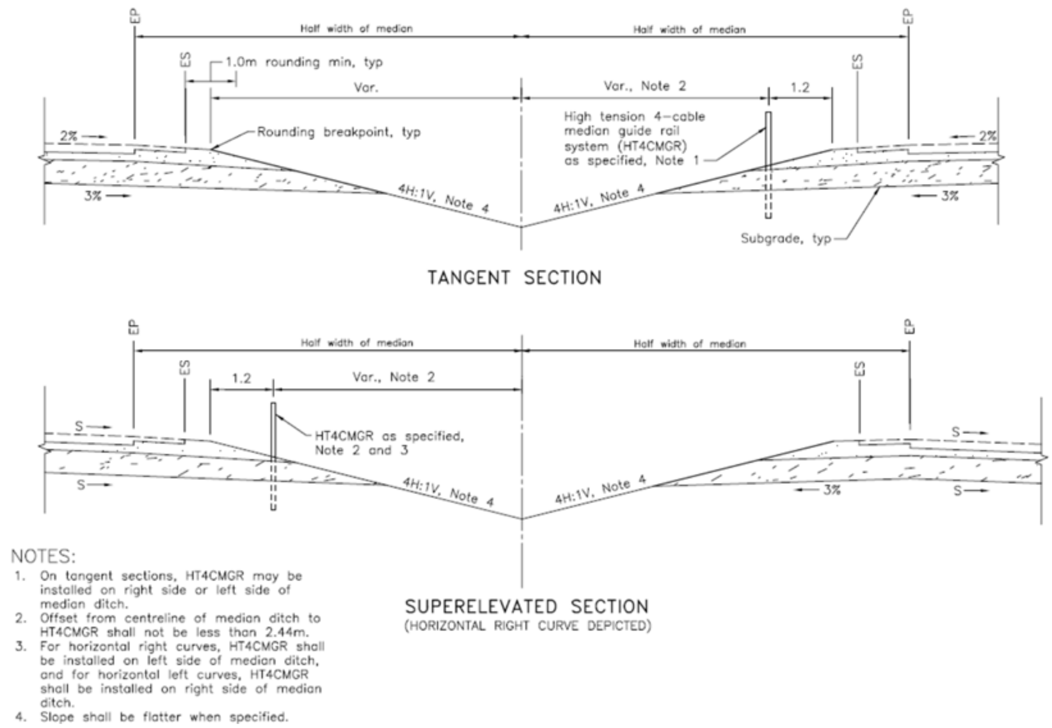


Figure 4-21: Typical HT4CMGR installation for rural median with 4H:1V slopes

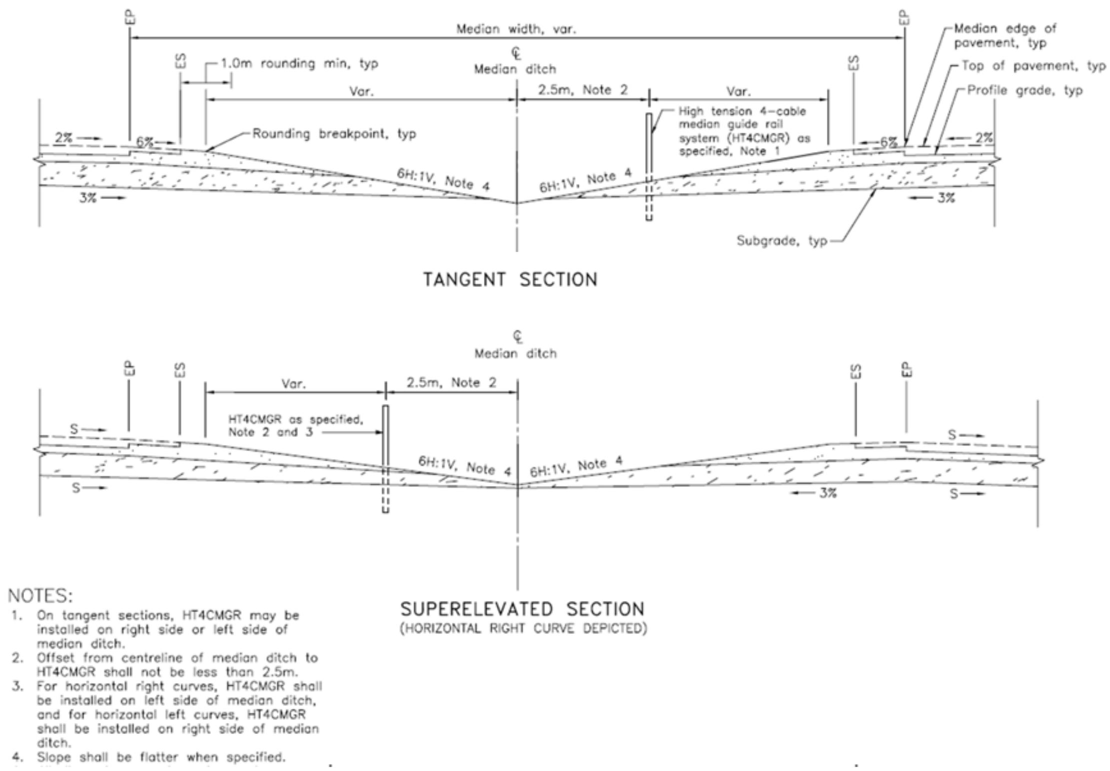


Figure 4-22: Typical HT4CMGR installation for rural median with 6H:1V slopes

Turnbuckles are used to achieve the specified tension in the cables according to Contract Documents and manufacturer’s instructions. Turnbuckles should be installed at 305 m intervals, and may be located above one another (eg. all four could be located above each other between same posts).

Modified HT4CMGR line posts may be installed over shallow culverts or other buried obstacles dependent on guidance from each manufacturer.

Length of need for the HT4CMGR system is dependent on type of system and terminal.

HT4CMGR installations should not be installed in front of or behind curbs.

When offset 1.22 m or more from the shoulder breakpoint, which is at least 2.72 m from edge of median shoulder assuming 1.0 m wide median shoulders and 1.0 m roundings, reflectors are not recommended. Shoulder rumble strips and post mounted delineators or snowplow markers should continue to be installed along each side of median according to current MTO requirements.

Crashworthy proprietary end terminals should be installed on 6H:1V or flatter slopes as described below.

End Treatments and Terminals:

Crashworthy proprietary end terminals should be installed on 6H:1V or flatter slopes at least 2.44 m from the toe of slope which also intersects the opposite slope that is 4H:1V or flatter. The Gregory Safence 4-Cable barrier is terminated with the Safence Terminal while the Trinity CASS S3 4-Cable system is terminated using the Trinity HARP Terminal. Both systems meet the crash testing requirements of NCHRP Report 350 TL-3.

The area immediately downstream of the terminal anchor assembly measuring 23 m x 6 m should be clear and traversable.

Terminals should be delineated with an Object Marker and Snow Plow Marker placed 0.6 m from edge of closest shoulder breakpoint 2 m in advance of an approach end terminal or 2 m beyond a leaving end terminal to minimize potential for damage from snowplows and impacts by errant vehicles. When terminals are impacted by snowplows or errant vehicles, the terminal system is designed to release the cables during impacts, making the entire length of the HT4CMGR installation non-functioning until repaired.

Transitions:

There are currently no acceptable transitions available for transitioning and connecting HT4CGR to semi-rigid barriers or rigid barrier systems.

Terminating HT4CMGR systems in vicinity of bridges or overpasses will need to overlap with semi-rigid barriers or rigid barrier systems terminated with a crashworthy terminal. Systems cannot be interconnected.

4.3.2 Type M Double Rail Steel Beam Guide Rail

Semi-rigid median barrier systems are generally only installed on freeways within narrow medians less than 10 m wide as an alternative to concrete median barrier when a permeable barrier system is required to not block overland flow routes where relief flow is required across a roadway during flood events.

Type M double rail SBGR when posts are installed behind curb meets the crash test acceptance requirements of NCHRP Report 350 TL-3 and is expected to be crash tested to MASH in the coming years.

Description:

Type M double rail SBGR is similar to Type M SBGR described earlier in section 4.2.2 other than it has two standard W-beam rails mounted to two standard 30 cm deep routed wooden or plastic offset blocks attached to each side of the standard 1829mm long W150x13 steel posts spaced at 1.905 m intervals. The top of rail height is the same as Type M SBGR with top of rail set at 785 mm +/- 25 mm.

Advantages and Disadvantages:

The main advantages of Type M double rail SBGR are:

- Lower construction cost than rigid systems;
- Permeable barrier system which should not block overland flow routes where relief flow is required across a roadway during flood events.

The main disadvantages of Type M double rail SBGR are:

- Higher maintenance requirements compared to rigid systems;
- Higher dynamic deflection than rigid systems;
- Will not block potential headlight glare from opposing traffic;
- Steel posts will potentially conflict with buried drainage systems and require curbs to direct surface drainage away from posts longitudinally along median to catch basins;
- Will not accommodate installation of small signs, luminaires, or large sign support legs; and
- Lower performance crash test level than TL-5 tall wall median barrier and 4.3.2.2 Guardian 5 Steel Beam Median Barrier.

Design Guidance:

Much of the design guidance for Type M SBGR provided in section 4.2.2 applies to Type M double rail SBGR.

Type M double rail SBGR may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which will likely function as a drainage swale.

For narrow medians where adjacent lanes drain towards the median, Type M double rail SBGR should be installed within a raised island with face of curbs offset no greater than 125 mm in front of each w-beam rail. The centre of raised island should not be paved with asphalt or concrete, and should be backfilled with compacted granular base and treated with granular sealant. Figure 4-21 shows configuration.

Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the Type M steel posts at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of the system installations should be transitioned from/to rigid barrier systems or terminated with a median end terminal or crash cushion.

End Treatments and Terminals:

In order to allow development of tensile strength in the Type M double rail SBGR system, both ends of the system installation need to be transitioned and anchored to a rigid barrier system, or transitioned and anchored to an appropriate double sided crash cushion. Both situations will require a non-standard design to be issued by Highway Design Office.

4.3.3 Australian Construction Products Sentry Median Barrier W Beam System

Description:

ACP Sentry Median Barrier is a double-sided version of the ACP Sentry barrier that meets the crash test acceptance requirements for MASH TL-3. The barrier consists of the same posts, rails and mounting hardware as the roadside version, with two rails mounted back-to-back to every other post.

Figure 4-23: ACP Sentry W Beam Median Barrier

The median system may be installed in a granular or asphalt median and has a working width of 1.49m. When a granular median is used, granular sealing shall be applied as appropriate to mitigate erosion and gravel tracking onto the roadway. The median must be flush, the system may not be installed adjacent to barrier curb.

Design Guidance:

ACP Sentry Median SBGR may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which will likely function as a drainage swale.

ACP Sentry Median SBGR is not tested in conjunction with concrete curb and gutter and should only be installed in flush medians. Medians may be granular or asphalt with leave-outs cut to allow for post rotation. Exposed granular surfaces should have granular sealing applied to prevent erosion.

Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the C-posts at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Transitions and End Treatments:

The Sentry Median Barrier may be anchored with either a compatible crash cushion or a Median SBEAT. A transition is required to double-sided conventional guiderail with offset blocks.

4.3.4 Ingal Civil Products Ezy Guard 4 Median Barrier W Beam System

Description:

Ingal Civil Products Ezy Guard 4 Median Barrier is a double-sided version of the Ingal Civil Products Ezy Guard 4 barrier that meets the crash test acceptance requirements for MASH TL-3. The barrier consists of the same posts, rails and mounting hardware as the roadside version, with two rails mounted back-to-back to every other post.

Figure 4-24 Ingal Civil Products Ezy Guard 4 W Beam Median Barrier

The median system may be installed in a granular or asphalt median and has a working width of 1.65m. When a granular median is used, granular sealing shall be applied as appropriate to mitigate erosion and gravel tracking onto the roadway. The median must be flush, the system may not be installed adjacent to barrier curb.

Design Guidance:

Ingal Civil Products Ezy Guard 4 Median SBGR may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter, and may be installed with a flare rate up to 10:1. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which will likely function as a drainage swale.

Ingal Civil Products Ezy Guard 4 Median SBGR is not tested in conjunction with concrete curb and gutter and should only be installed in flush medians. Medians may be granular or asphalt and do not require leave-out cut to allow for post rotation. Exposed granular surfaces should have granular sealing applied to prevent erosion.

Reflectors with a minimum reflective surface of 100 x 100 mm and flexibility to bend 90 degrees from vertical and self-restore are attached to the top of the steel Z-post at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Transitions and End Treatments:

The Ingal Civil Products Ezy Guard 4 Median Barrier may be anchored with either a compatible crash cushion or a Median SBEAT. A transition is required to double-sided conventional guide rail with offset blocks.

4.3.5 Guardian 5 Steel Beam Median Barrier

The Guardian 5 Steel Beam Median Barrier (G5) system was developed and successfully crash tested in 2016 to meet the crash test acceptance requirements of MASH TL-5.

Description:

ArcelorMittal and Gregory Industries developed their proprietary G5 steel beam median barrier system to meet the requirements of MASH TL-5. The system uses 3 m long high strength steel C posts spaced at 1.52 m intervals (vs 1.905 m for SBGR) with high strength thrie beam and w-beam rails mounted on steel offset blocks on each side. While these beams have the same geometry and appear to be similar to standard thrie beam and w-beam rails, they are 4.572 m long whereas standard rails are 3.810 m long. Having different post spacing and rail lengths from Type M SBGR will ensure that during installation only the longer high strength steel rails will attach to the posts. (eg., standard strength rails cannot mistakenly be used in field).

For the G5 steel beam median barrier system, the top of the w-beam rail is set 1513 mm above the pavement, whereas the top of the thrie beam is set at 894 mm above the pavement.

Dynamic Deflection and Working Width results from the MASH crash tests are summarized in Table 4-2.

- **Advantages and Disadvantages:**

The main advantages of G5 steel beam median barrier are:

- Similar construction cost to tall wall median concrete barrier;
- Higher performance test level than Type M double rail SBGR and HT4CMGR systems;
- Taller system results in reduced zone of intrusion for tractor trailers during TL-5 impacts when compared to tall wall median concrete barrier;
- Permeable barrier system which should not block overland flow routes where relief flow is required across a roadway during flood events;
- Taller height of system may eliminate more headlight glare than tall wall concrete median barrier (1513mm vs 1050 mm); and
- More forgiving than rigid tall wall median concrete barrier due to lower deceleration forces sustained by vehicle and occupants during impact.

The main disadvantages of G5 steel beam median barrier are:

- Higher maintenance requirements than rigid systems;
- Will not accommodate installation of small signs, luminaires, or large sign support legs; and

- Longer steel posts will potentially conflict with buried drainage systems and require curbs to direct surface drainage away from posts longitudinally along median to catch basins.
- Can't be installed in stepped medians which are common on superelevated horizontal curves.

Design Guidance:

Minimum installation length is 100 m.

MASH Crash Test	Test Vehicle	Impact Speed km/h	Impact Angle Degrees	Dynamic Deflection m	Working Width m
3-10	1100C	101	25.3	0.31	0.31
3-11	2270P	100	25.1	0.49	0.49
5-12	36000V	78.5	15.1	1.32	1.65

Table 4-2: Working Widths for Guardian 5 Steel Beam Median Barrier

System may be installed beyond the edge of median shoulders when the surface is 10H:1V or flatter. Steel posts should not be set at bottom of two intersecting 10H:1V slopes which would likely function as a drainage swale.

For narrow medians where adjacent lanes drain towards the median, system should be installed within a raised island with face of curbs offset no greater than 125 mm in front of each thrie-beam rail. The centre of raised island should not be paved with asphalt or concrete, and should be backfilled with compacted granular base and treated with granular sealant.

Retroreflective tape with a minimum reflective surface of 100 x 100 mm should be attached to the sides of the steel c-post between upper and lower beams at maximum intervals of 20 m on tangents. On horizontal curves, spacing of reflectors should be reduced according to requirements in OTM Book 11.

Approach and leaving ends of the system installations should be transitioned from/to tall wall concrete median barrier, or terminated with a double sided crash cushion.

Specifying a double sided crash cushion will require issuance of a non-standard design for the G5 steel beam median barrier system by Highway Design Office.

Figure 4-25: Guardian 5 Steel Beam Median Barrier System
Photo courtesy of Gregory Steel, Inc.

End Treatments and Terminals:

In order to allow development of tensile strength in the G5 steel beam median barrier system, both ends of the system installation need to be transitioned and anchored to a rigid barrier system, or transitioned and anchored to an appropriate double sided crash cushion. Both situations will require non-standard design to be issued by Highway Design Office.

4.3.6 Concrete Median Barrier

Concrete Median Barriers (CMB) are rigid barrier systems designed to redirect vehicles through resistance of lateral forces. Generally, rigid barrier systems differ from other barrier systems since they are not designed to yield upon vehicle impact and they do not deflect.

Concrete median barriers are the most commonly used type of median barrier in Ontario. The prevalence of CMB is due mainly to its low life-cycle cost, effective performance, and low maintenance characteristics, which make it suitable for high speed high volume highways with narrow medians. For opposing directions of travel on freeways with narrow medians, tall wall concrete median barrier should be used which meets MASH TL-5.

CMBs are typically classified by their shape and overall height above top of pavement.

Description:

The modified New Jersey shape concrete barrier has been used for all new installations of concrete median barrier since the early 1990s on the provincial highway system. For additional information about modified New Jersey shape concrete barriers, refer to Section 4.2.3.

Standard heights of CMB used on the provincial highway system are 825 mm and 1050 mm, which is measured from top of adjacent pavement to the top of barrier. These heights do not include the embedded part of the CMB below the top of pavement.

Slip-formed or cast-in-place 825 mm high Type M CMB and Type C CMB, and 1050 mm high Type TW CMB, also known as Ontario Tall Wall, specified on MTO contracts advertised after December 31, 2017 will meet the crash test acceptance requirements of MASH TL-3 and TL-5 respectively.

All three CMB configurations referenced above may be constructed in an asymmetric configuration to accommodate grade differentials typically found between opposing lanes on superelevated curves. The maximum grade differential that can be accommodated is 600 mm.

4.3.6.1 Type TW Concrete Median Barrier

Advantages and Disadvantages:

The advantages of Type TW CMB are:

- Lower maintenance requirements compared to flexible and semi-rigid systems;
- Higher profile addresses headlight glare;
- No dynamic deflection;

- Can be directly connected to structures with concrete TL-5 bridge rails; and
- System can function properly after moderate impacts.

The disadvantages of Type TW CMB compared to semi-rigid and flexible barrier systems are:

- Less forgiving due to higher deceleration forces sustained by vehicle and occupants during impacts;
- Closed drainage system required below barrier to accommodate drainage from median shoulders and lanes draining towards median;
- Will block overland flow in flood prone areas;
- May limit stopping sight distance on inside of horizontal curves with narrow median shoulders, especially when asymmetric CMB required.
- Construction cost is higher relative to semi-rigid median barrier systems; and
- After severe impacts by trucks, expensive repairs may be required to restore CMB.

Design Guidance

Type TW CMB is the desired median barrier system for installation on freeways with narrow medians less than 10 m wide, except where overland flow needs to be accommodated.

Type TW CMB may also be installed on freeways with narrow medians between core/collector systems, or between freeways and service roads.

The minimum installation length is 30 m, and there is no maximum installation length.

The traversable area between the travelled way and the barrier should be free of obstacles and irregularities, and be sloped no steeper than 10H:1V. This area should be paved, with a minimum depth of 75 mm over a width of at least 3.0 m on both sides of the TW CMB.

Approach and leaving ends of the system installations should be shielded with an appropriate end treatment or transitioned to / from another roadside barrier system.

Type TW CMB should not be installed more than 4.6 m from the edge of the travelled way. An exception is on the inside of horizontal curves, where it is necessary to maintain minimum stopping sight distance. Installation at greater offsets is generally not desirable as the cost of shoulder paving and maintenance becomes excessive.

Curbs should not be installed in front of CMB.

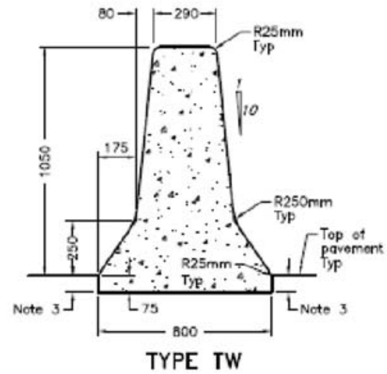


Figure 4-26: Tall Wall Concrete Median Barrier installation

End Treatments:

The blunt end of any rigid barrier system is a hazard if it is located where it may be hit by an errant vehicle. Each end of Type TW CMB system should be transitioned to a narrower CMB or treatment and terminated with an appropriate crash cushion.

Transitions:

Both approach and leaving end connections should conform to standard transition design requirements.

Standard designs are being finalized in 2018 for transitioning TW CMB to Guardian G5 Steel Beam Median Barrier system. Standard designs are currently available for connecting TW to TL-5 concrete bridge rails.

4.3.6.2 Type M and C Concrete Median Barrier

The 825 mm high Type M and C CMB are non-reinforced concrete median barrier systems. Type M and C CMBs are typically used as a separator barrier between two adjacent roadways with traffic flows in the same direction, such as core/collector systems.

Advantages and Disadvantages:

The advantages of Type M and C CMB compared to semi-rigid and flexible barrier systems are:

- Lower routine maintenance requirements when compared to semi-rigid systems;
- No dynamic deflection;
- Can be used on horizontal curves;

- Can be connected to structures; and
- System continues to function properly after most minor impacts, without any repair required.

The disadvantages of Type M and C compared to semi-rigid and flexible barrier systems are:

- Does not permit overland drainage flow;
- Storm sewer system is required in most situations; and
- Construction cost is higher relative to semi-rigid systems.

Design Guidance

There is no maximum installation length. The minimum installation length is 30 m.

The traversable area between the travelled way and the barrier should be free of obstacles and irregularities, and be sloped no steeper than 10H:1V. This area should be paved.

Approach and leaving ends of the system installations should be shielded with an appropriate end treatment or transitioned to / from another roadside barrier system.

Type M and C CMB is effective on high volume, high-speed roadways where there is a high frequency of collisions since routine maintenance is typically less for a rigid barrier system when compared to semi-rigid systems. Therefore, Type M and C is desirable in locations where the system will be installed close to the traveled way, where site access is limited, and/or where lane closures are costly and disruptive.

Paving of the adjacent shoulder is required to embed the CMB to prevent deflection of system when impacted.

Type M and C CMB should not be installed more than 4.6 m from the edge of the travelled way. An exception is on the inside of horizontal curves, where it may be necessary to maintain stopping sight distance. Installation at greater offsets is generally not desirable as the cost of shoulder paving becomes excessive.

Type M and C CMB performs all of the drainage functions of a curb and gutter system. Curb and gutter should not be located between the edge of travelled way and traffic face of CMB.

End Treatments

The blunt end of any rigid barrier system is a hazard if it is located where it may be hit by and errant vehicle. Each end of Type M and C CMB systems, where it is not transitioned to another barrier system should be treated appropriately with a crash cushion.

Transitions

Type M and C CMB can be connected to semi-rigid barrier systems including Type M SBGR. The standard transition and connection details reduce the likelihood of vehicle snagging, pocketing or penetration. Only standard transition and connection details should be used on the provincial highway system.

Both approach and leaving end connections should conform to standard transition design requirements.

Standard designs have been developed to transition from Type M and C CMB to concrete bridge rails.

4.4 Barrier End Terminals and Crash Cushions

All MTO contracts advertised after September 1, 2016 that included installations of new Steel Beam Energy Attenuating Terminals should have specified terminals that met the crash test acceptance requirements of MASH TL-3.

All MTO contracts advertised after December 31, 2016 that included installations of new Type M SBGR with approach end terminals located on horizontal curves with centerline radii less than 190m should have specified Steel Beam Terminals that met the crash test acceptance requirements of MASH TL-3.

All MTO contracts advertised after December 31, 2016 should no longer have specified new installations of Eccentric Loader Terminals (ELT) or Crash-Cushion Attenuating Terminals (C-CAT).

All MTO contracts advertised after May 25, 2009 that included the tender items for permanent and temporary energy attenuators (crash cushions) for installation at ends of permanent or temporary concrete barrier, should have specified energy attenuators that met the crash test acceptance requirements of MASH TL-2 or TL-3, dependent on the posted speed of the facility. NCHRP Report 350 systems may be used in categories where MASH systems are not available.

Errant vehicle impacts with the untreated ends of semi-rigid or rigid barrier systems or fixed objects have a high potential risk of serious injury to vehicle occupants. This is due to high deceleration forces or vehicle instability that would result. Barrier end terminals and crash cushions are used to reduce the severity of such impacts by attenuating collision energy through gradual vehicle deceleration or through vehicle redirection away from the fixed object.

Barrier end terminals and crash cushions primarily serve to lessen the severity outcome of collisions, rather than prevent them from occurring.

An end terminal is normally used at the end of a barrier system where traffic passes on one side of the barrier and protection from a head-on impact is necessary in one direction only. A crash cushion is normally used to shield the end of a median barrier system, a fixed object located in the median, or an object located within a gore area.

A crash cushion may also be used to shield an object on either side of a roadway, if it is more suitable and/or cost-effective than a barrier system.

Crash cushions are also used in work zones to shield the ends of temporary barrier systems.

End terminals and crash cushions are generally designed to safely stop and/or redirect passenger cars and light-duty trucks. For design impacts, these systems are designed to keep deceleration forces below specified limits, resulting in a lower risk of serious injury to vehicle occupants during impacts the system was designed for.

End terminals and crash cushions do not function in isolation. They are selected and designed as one element of an integrated roadside system that includes consideration of the roadway, shoulder, foreslopes, drainage facilities and the roadside environment. These elements should be designed to function in conjunction with one another to maximize safety benefits.

Design Guidance:

Grading between the travelled way and end terminals or crash cushions should be relatively flat (10H:1V or flatter). The terrain should be free of obstacles that may affect vehicle stability prior to the moment of contact with the end terminal or crash cushion. When the use of curb and gutter adjacent to end terminals or crash cushions is unavoidable, mountable curb should be used to maintain vehicle stability prior to impact.

The performance of end terminals and crash cushions is dependent on correct installation, maintenance, and post-crash repair. Careful attention should be paid during the design stage to system selection and specification, integration with other design elements, as well as orientation and positioning. Grading and anchorage requirements, length of need, and suitability to expected traffic characteristics should also receive proper attention.

All end terminals and crash cushions specified on provincial highway project are proprietary products. These products are available exclusively from the manufacturer or designated distributor for the area. Such products are generally purchased as a complete system, with ongoing logistical support (e.g. installer and repair training, technical assistance and replacement components) available from manufacturer or distributor.

4.4.1 SBGR End Terminals

The following steel beam guide rail end terminals are accepted and specified for use on the provincial highway system:

Steel Beam Energy Attenuating Terminal System (SBEAT):
- MASH MAX-Tension Terminal System
- MASH Sequential Kinking Terminal System
- MASH SoftStop Terminal System
- MASH SPIG Gating End Terminal System

Steel Beam Energy Attenuating Terminal System (SBEAT), Median:
- MASH MAX-Tension Median Terminal System

Steel Beam Terminal (SBT)
- MASH Slotted Rail Terminal System
- MASH Flared Energy Attenuating Terminal System

Crashworthy roadside devices should be installed, maintained, and inspected to ensure their condition reflects the as-tested configuration and adheres to manufacturer's requirements. Failure to comply with the nature in which these systems were tested can result in failure which could lead to serious injury or fatality of vehicle occupants.

Installation, maintenance and inspection of guide rail, end terminals, crash cushions, high tension cable guide rail, and small / intermediate sign support systems should be performed by persons with manufacturer-accredited training in these activities.

4.4.1.1 End Terminal Grading

All of the SBGR end terminals specified by the ministry are classified as "gating" systems, a term which describes their behavior when impacted at an angle near the impact head. A gating end terminal allows a vehicle impacting the nose or side of the system immediately downstream of the nose, to pass through the device. For impacts within the length of need, gating end terminals have redirectional characteristics that are compatible with the roadside barrier. Due to the gating performance of these systems, the area behind and beyond all end terminals should be traversable and free of fixed obstacles. This configuration is illustrated in Figure 4-25

Roadside grading should be designed to accommodate the operation of end terminals and crash cushions. Steel Beam Energy Attenuating Terminal (SBEAT) systems for SBGR installations are flared to reduce nuisance impacts and also require special accommodations in roadside grading and drainage facilities. The relatively flat area should extend at least 1.5 m behind the terminal nose in a direction away from the road so errant vehicles impacting the terminal (right shoulder installation) with the left front of the vehicle will not reach a high roll angle prior to impact. Figure 4-25 shows the desirable grading cross-sections for a new SBEAT installation along with flaring of the SBEAT.

Designers have the flexibility to extend the length of guide rail installations to a location where desirable grading requirements for a new SBEAT installation can be better accommodated.

Designers also have the flexibility to provide less than the desirable grading requirements for new end terminal installations when constrained by environmental or property restrictions. This may include reducing the desirable widening behind terminal post #1 and/or increasing the steepness of the slope behind the system. This should be documented in the project file.

Where the roadway is being widened for the installation of and SBEAT, drainage requirements need to be considered and addressed.

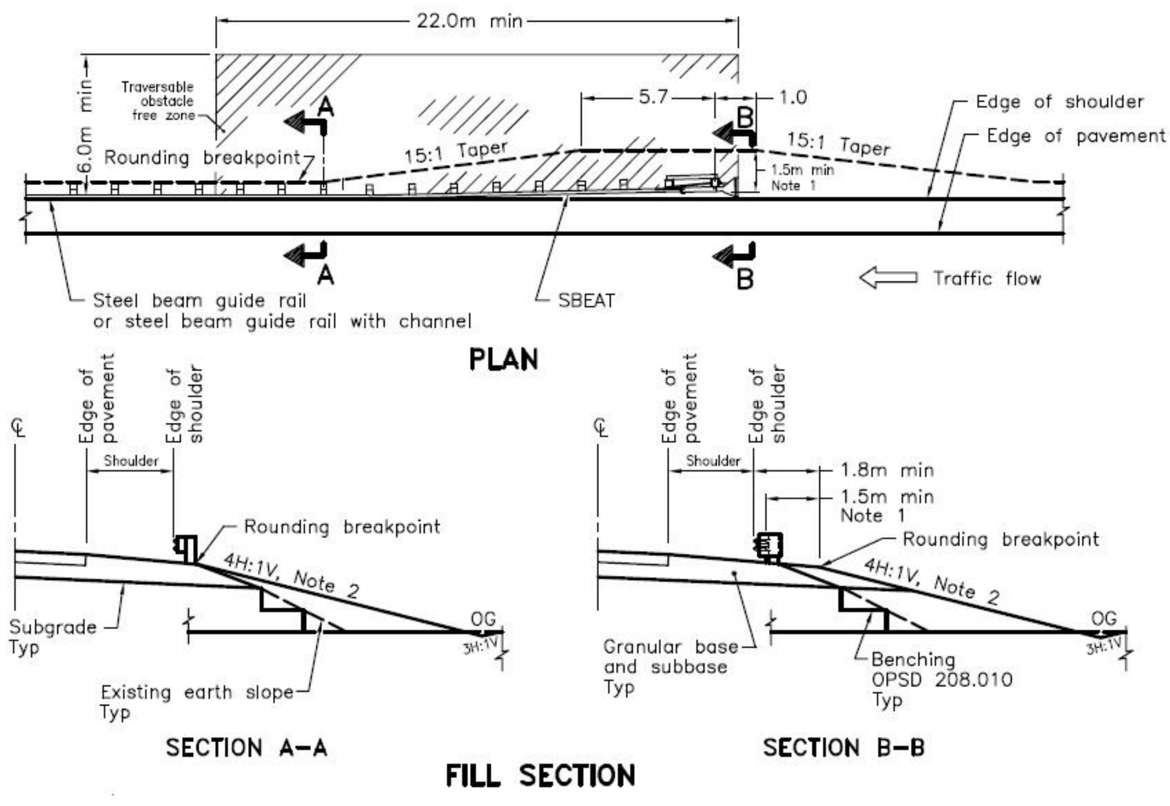


Figure 4-27: Desirable Grading for SBEAT Installations

See applicable standard for Notes

4.4.1.2 Max Tension Terminal System

The MAX-Tension tangent end terminal is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The system uses a tension-based design along with an energy absorbing coupler that features cutting tooth design. When impacted head-on, deceleration is controlled by friction developed in the tension cables and by cutting the downstream guide rail panels. When an angled side impact occurs beyond post 4, tension cables help the beams to redirect a motorist away from the obstacle being shielded along the system.

The MAX-Tension terminal uses many standard guide rail components such as steel posts, rails and offset blocks.

Figure 4-28: MAX-Tension Terminal System
Photo courtesy of Lindsay Corporation

Manufacturer: Lindsay Corporation – Barrier Systems
Web Site: http://www.barriersystemsinc.com

4.4.1.3 SoftStop Terminal System

The SoftStop tangent end terminal is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The system uses a tension-based design with a front anchor that is designed to allow the rail panels to remain anchored during end-on impacts. When an angled side impact occurs beyond post 3, the system redirects a motorist away from the obstacle being shielded along the system.

Figure 4-29: SoftStop Terminal System

Manufacturer: Trinity Highway Products
Web Site: http://www.highwayguardrail.com

4.4.1.4 MASH Sequential Kinking Terminal System

The MASH Sequential Kinking Terminal (MSKT) system is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The MSKT is a compression-based design which is an update to the Sequential Kinking Terminal (SKT) system that met NCHRP Report 350. During head-on impacts, the MSKT head slides over the W-beam guardrail and the rail is sequentially kinked as it moves through the impact head. The kinked guardrail exits the head behind the system away from the roadway and the vehicle is brought to a controlled stop. This is the same technology used by the SKT. Also similar to the SKT, angled impacts beyond post 3 are redirected along the system by the MSKT.

The MSKT impact head may be used for repairs of existing SKTs. However, use of the MSKT head on an existing SKT installation does not convert the existing SKT into a system that meets MASH. The MSKT also has a ground strut connecting posts 1 and 2 together at ground level, which the SKT does not use.

Figure 4-30: MSKT Installation
Photo courtesy of Road Systems, Inc.

As with all compression based terminal systems (MSKT, SKT, Eccentric Loader Terminal, Extruder Terminal and CAT), the 20 cm x 20 cm bearing plate at post #1 needs to be correctly positioned with bolt located closer to bottom of plate (e.g., center of bolt is 12.5 cm below top of plate and 7.5 cm above bottom of plate) as shown in Figure 4-29. It is acceptable to place a retainer/tie over the bearing plate to prevent rotation. The anchor cable is taut and correctly installed.

Figure 4-31: Correct Orientation of Bearing Plate on Compression Based Terminals Photo courtesy of Road Systems, Inc.

Manufacturer: Road Systems Inc.
Web Site: http://www.roadsystems.com

4.4.1.5 SPIG Gating End Terminal

The Safety Products Innovations in Guardrail (SPIG) Gating End Terminal (SGET) system is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3. It was developed by SPIG Industries in Bristol Virginia.

During head-on impacts, the SPIG head engages the vehicle and impacts Post 1 which breaks away. The impact head then slides over the W-beam guiderail and the rail is flattened as it moves through the impact head while Posts 2 through 8 break away at ground level. The flattened guardrail exits the head behind the system away from the roadway and the vehicle is brought to a controlled stop. The system is gating-redirective, angled impacts beyond Post 3 are redirected along the system by the SGET.

Figure 4-32: SPIG Gating End Terminal Installation
Photo courtesy of SPIG Industries

Manufacturer: SPIG Industries
Website: https://spigindustry.com/sget

4.4.1.6 Max Tension Median Terminal

The MAX-Tension Median end terminal is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3. The system functions similarly to the roadside Max Tension system. The main difference between the two systems is the wider impact head which allows for termination of a double-sided 785 mm high guiderail system.

The system uses a tension-based design along with an energy absorbing coupler that features cutting tooth design. When impacted head-on, deceleration is controlled by friction developed in the tension cables and by cutting the downstream guide rail panels. When an angled side impact occurs beyond post 3, tension cables help the beams to redirect a motorist away from the obstacle being shielded along the system.

The MAX-Tension Median terminal uses many standard guide rail components such as steel posts, rails and offset blocks.

Figure 4-33: Max Tension Median Terminal Installation
Photo courtesy of Lindsay Corporation

Manufacturer: Lindsay Corporation – Barrier Systems
Web Site: http://www.barriersystemsinc.com

4.4.1.7 Median Attenuating Trend Terminal

The Median Attenuating Trend Terminal or MATT is a proprietary gating redirective energy absorbing system that meets the crash test acceptance requirements of MASH TL-3.

The system absorbs energy through a combination of rail shearing and post yielding. When impacted head-on, the rail segment is pushed back and past the blockout. The tabs punched in the rail engage with the blockout assembly and the steel between the tabs is sheared. Additionally, as a vehicle reaches a post, the upper portion breaks away from the lower portion.

When an angled side impact occurs beyond post 2, the system redirects an impacting vehicle away from an obstacle being shielded by the system.

Figure 4-34: Median Attenuating Trend Terminal
Photo courtesy of Trinity Industries

Manufacturer: Trinity Industries
Web Site: http://www.trinityhighway.com

4.4.1.8 Slotted Rail Terminal

The Slotted Rail flared end Terminal (SRT) is a proprietary gating non-energy absorbing, end terminal system that meets the crash test acceptance requirements of MASH TL-3.

The system is installed with a 10:1 (5.7^0) flare with rail at post #1 offset 1.22 m away from the shoulder.

When an angled side impact occurs beyond post 4, the system redirects a motorist away from the obstacle being shielded along the system.

This system is acceptable for Steel Beam Terminal (SBT) item and is typically specified for use on provincial highway projects where Type M SBGR starts on either the inside or outside edge of a horizontal curve with centerline radii less than 190m.

Figure 4-35: Slotted Rail Terminal
Photo courtesy of Trinity Highway Products

Manufacturer: Trinity Highway Products
Web Site: http://www.highwayguardrail.com

4.4.1.9 MASH Flared Energy Attenuating Terminal

The MASH Flared Energy Attenuating Terminal (MFLEAT) is a proprietary gating energy absorbing, end terminal system that meets the crash test acceptance requirements of MASH TL-3.

The system is installed with a 13:1 (4.3^0) flare with rail at post #1 offset 0.91 m away from the shoulder. The system may be installed at an offset of 1.22m from the shoulder provided the flare rate of 13:1 is maintained. This requires the start of the flaring to be extended further down the length of the guiderail.

When an angled side impact occurs beyond post 4, the system redirects a motorist away from the obstacle being shielded along the system.

This system is acceptable for Steel Beam Terminal (SBT) item and is typically specified for use on provincial highway projects where Type M SBGR starts on either the inside or outside edge of a horizontal curve with centerline radii less than 190m.

Figure 4-36: MASH Flared Energy Attenuating Terminal
Picture courtesy of Road Systems Inc

Manufacturer: Road Systems Inc.
Web Site: http://www.roadsystems.com

4.4.2 Crash Cushions

Crash cushions are classified into the following categories based on their behavior upon impact:

- Redirective, gating
- Redirective, non-gating; or
- Non-redirective, gating:

A redirective, gating crash cushion allows a vehicle impacting the side of the unit at an angle, near the nose, to pass through the crash cushion. In head-on impacts, a redirective, gating crash cushion should bring the impacting vehicle to a controlled stop. The beginning of length of need of a redirective, gating crash cushion varies, depending on the specific crash cushion employed. For impacts within the length of need (e.g. downstream of the gating nose portion of the crash cushion), a gating, redirective crash cushion has similar redirectional characteristics as a standard roadside barrier.

A redirective, non-gating crash cushion is capable of redirecting a vehicle impacting the side of the crash cushion at an angle along the unit's entire length. In head-on impacts, a redirective, non-gating crash cushion should bring the impacting vehicle to a controlled stop. The length of need of a redirective, non-gating crash cushion starts from the nose. For impacts within the length of need, a redirective, non-gating crash cushion has the same redirectional characteristics as the adjacent barrier system.

A non-redirective, gating crash cushion cannot redirect vehicles impacting anywhere along its length. In head-on impacts, a non-redirective, gating crash cushion should bring the impacting vehicle to a controlled stop. Vehicles impacting the sides of a non-redirective, gating crash cushion at an angle may either be contained, proceed through the crash cushion or be deflected, depending on their impact angle, impact point, speed, and weight.

4.4.2.1 Summary of Crash Cushions

The crash cushions (energy attenuators) currently accepted and specified for installation as permanent systems on provincial highway projects are listed in Table 4-3.

Energy Attenuator	NCHRP Report 350 or AASHTO MASH Crash Test Level		Permanent Installation					
	TL-2	TL-3	Narrow (NA)	Wide (WI)	Extra Wide (EW)	Super Wide (SW)	High Exposure (HE)	Single Sided (SS)
TAU-M System (Note 1)	Yes	Yes	Yes	No	No	No	No	No
TAU-II Wide System (Note 2)	Yes	Yes	No	Yes	No	No	No	No
TAU-II Extra Wide System	Yes	Yes	No	No	Yes	No	No	No
Quadguard M10 System (Note 1)	Yes	Yes	Yes	No	No	No	No	No
Quadguard M10 Wide System (Notes 1 and 2)	N/A	Yes	No	Yes	No	No	No	No
Quadguard Wide System (Note 2)	Yes	Yes	No	Yes	No	No	No	No
Quadguard Extra Wide System	Yes	Yes	No	No	Yes	No	No	No
Quadguard Super Wide System	No	Yes	No	No	No	Yes	No	No
Delta System	Yes	Yes	Yes	No	No	No	No	No
QuadTrend	No	Yes	No	No	No	No	No	Yes
BB-Beat	No	Yes	No	No	No	No	No	Yes
Smart System (Note 1)	Yes	Yes	Yes	No	No	No	Yes	No
Hercules System (Note 1)	N/A	Yes	Yes	No	No	No	No	No

Note:
1. AASHTO MASH crash test compliant system.
2. The Quadguard M10 Wide (meeting AASHTO MASH TL-3) shall be used for Permanent Unidirectional configurations requiring a TL-3 crash test compliant system. For Permanent Unidirectional configurations requiring a TL-2 crash test compliant system and for all Bidirectional configurations of Energy Attenuator, Wide, systems listed on Table 1 and meeting NCHRP Report 350 shall be used.

Table 4-3: Permanent Energy Attenuators

Test Level and Posted Speed

Crash cushions accepted for use on the provincial highway system should meet the crash test acceptance requirements of AASHTO MASH test levels 2 or 3 (TL-2 or TL-3). NCHRP Report 350 systems may still be listed if not MASH compliant systems were yet implemented due to availability. Examples of the continuous use of legacy systems include wide, extra wide and super wide systems. The list of permanent energy attenuators is updated frequently. Designers should find the latest list in the ministry's contract preparation system. For convenience, the latest list is also found in the MTO Technical Publications website.

For each crash cushion installation, the appropriate test level should be determined based on the posted speed of the roadway. TL-2 configurations are specified for low-speed installations with posted speeds of less than 70 km/h. TL-3 configurations are specified for high-speed installations with posted speeds of 70 km/h and greater.

Redirective, Gating Systems

The systems listed under the Single Sided column in Table 4-3 are redirective, gating Crash Cushions and are specified for permanent installations only. These crash cushions should be used in locations where vehicles will impact the system from one side only, typically on roadside shoulders. A traversable area free of fixed obstacles is required behind and beyond the system as shown in Figure 4-35.

Desirable grading, as shown in Figure 4-35 should be used at all installations of redirective, gating crash cushions.

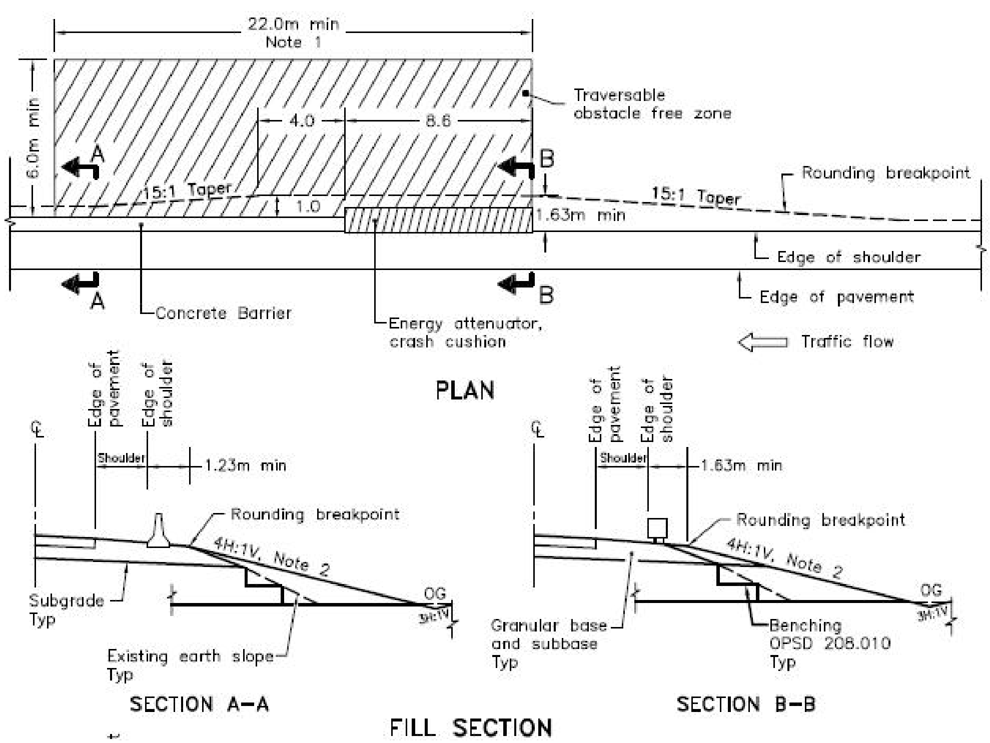


Figure 4-37: Desirable Grading for Single Sided Energy Attenuating Terminals

Redirective, gating crash cushions should not be installed in a location where backside impacts are possible (e.g., in gore areas), or in a narrow medians where backside, opposite direction impacts are possible.

Redirective, gating systems are currently only available in a TL-3 configuration.

Redirective, Non-Gating Systems

The systems listed under the Narrow, Wide, Extra Wide, Super Wide and High Exposure columns in Table 4-3 are redirective, non-gating crash cushions. Following a design impact, these systems can typically be repaired. However, major component replacement may be required in order to make the entire system crashworthy again.

The QuadGuard, QuadGuard M-10, Tau-II, TAU-M and Smart crash cushions are specified for permanent and temporary use.

The Smart system listed under the High Exposure column in Table 4-3 is specified for locations where there is a high risk of impact such as in the gore of a core / collector transfer. The Smart is desirable in locations where the system will be installed close to the traveled way, where site access is limited, and/or where lane closures are costly and disruptive. The Smart system has been proven to be the least expensive of all crash cushions specified by MTO to repair after design impacts, typically just requiring replacement of two shear bolts after the system is pulled back.

All of the accepted and specified redirective, non-gating systems can be installed in unidirectional and bidirectional configurations.

Redirective, non-gating systems are available in TL-2 and TL-3 configurations.

Terrain and Foundation Requirements

Crash Cushions are typically tested on paved, flat and level terrain. It is desirable to install crash cushions on relatively flat terrain, and the traversable area between the travelled portion of the roadway and the device should be free of obstacles and irregularities. Approaches to the crash cushion should be 10H:1V or flatter. A traversable area, free of significant fixed objects, should be provided adjacent and beyond the crash cushion.

Crash cushions should not be placed on surfaces with a crossfall greater than 6%.

All permanent crash cushions should be installed on a new reinforced concrete pad, with the exception of the Box Beam Bursting Energy Absorbing Terminal, which is installed on driven steel posts into compacted granular base. If an existing concrete surface or pad can be used to support the crash cushion, its surface must be in good condition in order to accommodate installation of anchors for the system.

Temporary crash cushions may be anchored to existing concrete surfaces, asphalt over compacted granular, or to asphalt over concrete. The existing surface must be in good condition in order to provide a smooth operating surface. The following dimensions represent the minimum foundation requirements for temporary crash cushion installation:

- Existing Concrete Surface:
  - Minimum 200 mm deep concrete with 28 MPa minimum compressive strength
- Asphalt over Compacted Granular:
  - Minimum 150 mm asphalt over a minimum 150 mm compacted granular
  - The asphalt must extend a minimum of 500 mm beyond the anchor bolts
- Asphalt over Concrete
  - Minimum 75 mm asphalt over a minimum 75 mm concrete with 28 MPa minimum compressive strength

Where temporary crash cushions are required to be placed on the inside of horizontal curves, the geometry of the proposed location should be checked to ensure that the crash cushion, and downstream barriers placed tangent to the crash cushion, will not result in excessive encroachment of the crash cushion into the shoulder or any encroachment into the travelled lane when installed. If such a conflict is identified, alternative locations should be considered which may require lengthening of a temporary construction barrier run or an alternative staging arrangement.

Curb and Gutter

Crash cushions should not be installed within close proximity to barrier curb and gutter. Where curb and gutter is required, mountable curb should be used starting approximately 15 m in front of the crash cushion and as far back as the system’s backup.

Delineation of Crash Cushions

A crash cushion typically does not reduce the frequency of impacts. The intent of a crash cushion is to lessen the severity of impacts when they do occur. However, delineation of the crash cushion may provide some reduction in the frequency of collisions with crash cushions.

Each permanent and temporary crash cushion installation should include appropriate delineation. For permanent installations, delineation should include a standard object marker and snow plow marker. For temporary installations, delineation should include a standard object marker and snow plow marker as well as flexible delineator posts when the crash cushion is located in a gore area or in a location where the shoulders are less than 2.0 m in width.

When installed on a paved surface, the signs should be mounted on a surface mounted flexible post. When installed on a granular surface, the signs should be mounted on a steel U channel post.

4.4.2.2 Box Beam Bursting Energy Absorbing Terminal

The Box Beam Bursting Energy Absorbing Terminal (BB-BEAT) System is a proprietary redirective, gating, single sided crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-3.

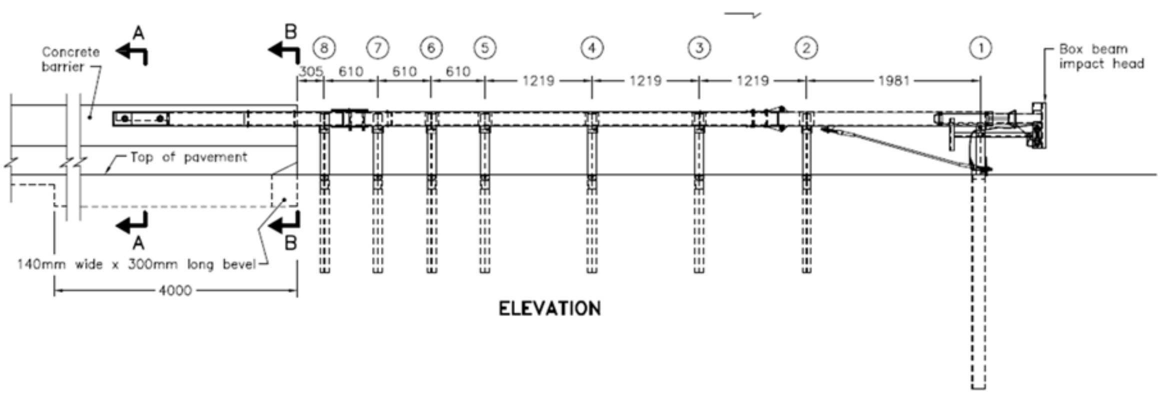


Figure 4-38: Box Beam Bursting Energy Absorbing Terminal

For head on impacts, the system absorbs energy in three stages. The impact head will engage the front of the vehicle and will be pushed forward along the stage one box beam rail element. The impact head will then contact the post breaker beam and break off the first steel breakaway post, releasing the cable anchorage. The tapered mandrel will split the box beam. If the vehicle has sufficient energy, it will continue into the stage two box beam rail element in the same manner, progressively splitting the box beam as the vehicle moves along. The system is designed to dissipate the energy from a 2000 kg pick up truck within the first two stages. However, additional capacity is provided by the third stage box beam rail element.

When the BB-BEAT is hit at an angle between the impact head and the third post, the impacting vehicle will gate through the system in a controlled manner and travel in behind the system before coming to rest.

The cable anchorage system provides the necessary tensile strength in the box beam rail to resist and redirect impacts downstream of the third post.

The BB-BEAT is typically used to shield the ends of concrete roadside barriers. It should only be used in locations where vehicles will impact the system from one side only. The BB-BEAT is acceptable and specified for permanent use only as a single sided crash cushion for permanent installations.

Manufacturer: Road Systems, Inc.
Web Site: http://www.roadsystems.com/

4.4.2.3 QuadTrend 350 End Treatment System

The QuadTrend is a proprietary redirective, gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-3.

Figure 4-39: QuadTrend Terminal

The system is 5.87 m in length. The post slip bases are anchored to a reinforced concrete pad and the rear end of the system is anchored to the concrete barrier wall using an offset transition panel. The front end of the redirecting cable is anchored to the concrete foundation in front of the first post. The rear end of the redirecting cable is routed through the first post and then extends at an angle of 25 degrees away from the system to an anchor block located 3.0 m behind the system on the roadside slope.

For head on impacts, the system simultaneously collapses and moves laterally along the redirecting cable to redirect an impacting vehicle away from the end of the concrete barrier. As the system collapses, the Quad-Beam fender panels telescope rearward and the posts shear at the slip bases. The sand-filled containers help dissipate collision energy. The Quad-Beam fender panels redirect the vehicle away from the hazard during side and reverse direction impacts. The QuadTrend System is typically used to shield the ends of concrete roadside barriers.

The QuadTrend should be used in locations where vehicles will impact the system from one side only. This will typically include roadside shoulders where there is there is sufficient space to provide an area behind and beyond the system that is traversable and free of fixed obstacles for a width of 6.0 m and a length of 22.0 m. The QuadTrend System is acceptable and specified for permanent use only as a single sided crash cushion for permanent installations.

Manufacturer: Energy Absorption Systems, Inc.
Web Site: http://www.energyabsorption.com

4.4.2.4 QuadQuard and QuadGuard M10 Systems

The QuadGuard System is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3. The QuadGuard M10 version of the system meets the requirements of MASH TL-2 and TL-3.

The system consists of a series of energy-absorbing cartridges supported by a framework of steel diaphragms and Quad-Beam fender panels. The self-supporting nose consists of a formed plastic wrap and an energy-absorbing cartridge. The system uses a centre monorail base that resists lateral movement during side impacts and a tension strut backup structure that anchors the system and resists movement during head-on impacts. The monorail base and tension strut backup are anchored to the foundation.

Figure 4-40: QuadGuard M-10
Photo courtesy of Energy Absorption Systems, Inc.

For head on impacts, the cartridges absorb the impact energy while the fender panels telescope rearward on the diaphragms that slide along the monorail base as the system collapses. The tension strut backup provides anchorage for the system.

The QuadGuard System is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The QuadGuard System is acceptable and specified for permanent and temporary use.

The narrow system is typically used to shield the ends of concrete barrier. The wide and extra wide systems are typically used to shield the ends of two runs of concrete barrier that meet at gore or median locations or for shielding fixed objects such as bridge piers.

Currently the Quad Guard M10 is only available as a narrow system. The QuadGuard system shall continue to be used for wide, extra wide and super wide applications. See Table 4-3 for details.

Manufacturer: Energy Absorption Systems, Inc.
Web Site: http://www.energyabsorption.com/index.asp

4.4.2.5 SMART Cushion

The Smart System is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3, and was subsequently crash tested without any modifications to MASH TL-3.

Figure 4-41: SMART Unidirectional Crash Cushion

For head on impacts, the system telescopes rearward as the side panels slide one over the next. The system is speed dependent and stops small vehicles by the hydraulic ram automatically regulating the stopping force exerted on the vehicle. Therefore, small vehicles are stopped at a slower rate than larger vehicles. This minimizes the deceleration forces on the vehicle occupants.

The Smart Cushion is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The Smart Cushion is acceptable for permanent and temporary use.

The Smart Cushion is categorized as a low maintenance system that is suitable to locations where there is high exposure and risk of impact such as in the gore of a core/collector transfers. Following most head on impacts, a trained repair crew can reset an impacted Smart Cushion in 30 to 60 minutes. In addition, it has been documented that more than 80% of Smart Cushion repairs required replacement of only the two shear bolts. In side impacts, the fender panels often receive little to no damage. As a result, repair crew exposure to traffic and motorist inconvenience is typically minimized as well as repair cost.

Manufacturer: SCI Products, Inc.
Web Site: http://workareaprotection.com/attenuators/

4.4.2.6 TAU-II and TAU-M Systems

The TAU-II System is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3. The TAU-M version meets the crash test acceptance requirements of MASH TL-2 and TL-3.

The system consists of a series of energy absorbing cartridges supported by a framework of steel diaphragms and telescoping thrie beam side panels.

The nose consists of a formed plastic wrap. The system uses two cables to resist lateral movement during side impacts and a compact backstop structure that anchors the cables and resists movement during head-on impacts.

The cables are attached to the compact backstop at the rear of the system and anchored to the foundation at the front of the system. The compact backstop is anchored to the foundation. The cables pass through the diaphragms, which are not anchored to the foundation.

Figure 4-42: TAU-M Narrow System

For head on impacts, the cartridges absorb the impact energy while the fender panels telescope rearward on the diaphragms that slide along the cables as the system compresses. The compact backstop(s) and front cable anchor(s) are bolted to the reinforced concrete pad according to manufacturer guidelines. The fender panels, diaphragms, and cables redirect vehicles during side and reverse direction impacts.

The TAU-M system is currently only available for narrow installations. For wide and extra wide applications, the TAU-II system shall continue to be used. See Table 4-3 for additional information.

Manufacturer: Barrier Systems Inc.
Web site: http://www.barriersystemsinc.com/

4.4.2.7 SMA Hercules

The SMA Hercules system is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of MASH TL-3.

The system consists of a series of all-steel collapsible beams, split into ten bays which slide on a steel base rail which is in turn fastened to a steel base plate. A frontal sliding trolley sits at the upstream end of the system and functions as the nose. The base and rail as well as the 4-beam side panels resist lateral movement during side impacts and a backstop anchors the system and resists movement during head-on impacts. The steel base and backstop are anchored to the foundation.

Figure 4-43: SMA Hercules

For head on impacts, the frontal sliding trolley is pushed along the rail into the collapsible beams which absorb the impact energy as the system collapses. The supports which connect the beams to the base collapse, also dissipating impact energy. The backstop provides anchorage for the system.

The SMA Hercules is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The SMA Hercules is acceptable and specified for permanent and temporary use.

Currently the SMA Hercules is only available as a narrow system, and only in a TL-3 configuration although it is appropriate for low-speed installations as well.

Manufacturer: Safety Modular Absorber
Web site: http://www.smaroadsafety.com

4.4.2.8 Delta Crash Cushion

The Delta system is a proprietary redirective, non-gating, crash cushion that meets the crash test acceptance requirements of MASH TL-3.

The system consists of a series of thrie beam fender panels supported by a framework of steel diaphragms. The nose piece is attached to the front of the system using four bolts. The dual rail base resists lateral impacts. The base of the system is anchored to the foundation.

Figure 4-44: Delta Crash Cushion

For head on impacts, a series of shear bolts tears through pre-punched cut-outs in the sides of the thrie beam panels, dissipating the impact energy.

The Delta system is a crash cushion used to shield the ends of barrier systems or fixed objects that may be impacted from both sides in a unidirectional or bidirectional installation. The Delta system is acceptable and specified for permanent and temporary use.

Currently the Delta is only available as a narrow system, and only in a TL-3 configuration although it is appropriate for low speed installations as well.

Manufacturer: Traffix Devices
Website: https://www.traffixdevices.com/products/attenuators/delta

4.4.3 Barrier System Transitions and Connections

Transitions between different barrier systems are designed to withstand vehicle impacts in the vicinity of the transition between barrier systems of differing rigidity, shape, mounting height, and performance characteristics. This is typically accomplished in a gradual manner because abrupt changes in barrier characteristics such as rigidity or shape could result in a vehicle pocketing or snagging in the vicinity or the transition.

Standard transition designs are available for use on Provincial Highways. Transitions are designed for either one-way or two-way traffic. Care must be taken to ensure that the appropriate standard transition is selected.

4.4.4 Existing In-Service Systems

End terminal and crash cushion design has evolved over the past 40 years along with crash test acceptance criteria. Road authorities, including the ministry, are continually updating and/or implementing standard designs for new hardware. As such, the existing in-service road safety hardware systems represent a broad range of performance characteristics, reflecting the standards-of-the-day when each was installed. While some systems may not meet the current testing procedure, existing in-service systems should still continue to perform on the provincial highway system and may remain in-service until the end of their service lives. An exception to this is for systems that were crash tested according to procedures that predate NCHRP Report 350, such as NCHRP Report 230 and its predecessors. Such systems, though now rare on the provincial highway network, are approximately 30 years old at a minimum and may have deteriorated plastic, steel and anchoring components and should be replaced with currently specified system on all capital projects.

4.5 Poles and Sign Support Systems

Since 2011, all new permanent small sign support systems installed on capital construction contracts on high speed provincial highways should have been breakaway and met the crash test acceptance requirements of NCHRP Report 350 TL-3 unless located behind an appropriate length of existing barrier offset appropriately to accommodate barrier working width. When signs are located behind an appropriate length of barrier, or for low-speed urban installations are located behind barrier curb, both breakaway or non-breakaway small sign support systems are acceptable.

Since March 2, 2017, all new permanent intermediate sign support systems installed on capital construction contracts on high speed provincial highways should have been breakaway and met the crash test acceptance requirements of NCHRP Report 350 TL-3 unless located behind an appropriate length of existing barrier offset appropriately to accommodate barrier working width.

Since the late 1980s, all large sign assemblies consisting of extruded aluminum sign panels generally 2.4 m and wider with total sign areas ranging from 2.9 m^2 to 23.8 m^2 installed on capital construction contracts on provincial highways should have been designed and installed according to the latest edition of the Ontario Traffic Manual (OTM) Book 3. OTM Book 3 provides standards and guidelines for the design of large aluminum extruded signs on wood column and steel column breakaway and non-breakaway sign support structures for various sizes of sign assemblies on various slopes. OTM Book 3 provides standard drawings for each sign support structure which require the design and completion of fill-in tables and dimensions, and shall bear the seal, date and signature of a Professional Engineer. These installations should be breakaway unless being installed behind an appropriate length of existing barrier systems offset appropriately to accommodate barrier working width. For additional details for design and installation of large sign support systems, refer to the latest edition of OTM Book 3.

New barrier systems should not be installed or extended on provincial highway projects for the sole purpose of protecting new or relocated large sign support assemblies when design of breakaway sign support systems are practical and/or sign could be located elsewhere behind an appropriate length of existing barrier offset appropriately to accommodate barrier working width.

Large overhead signs and cantilever signs on high speed highways should be located behind an appropriate length of existing barrier system offset appropriately to accommodate barrier working width. Overhead and cantilever signs mounted on a crashworthy median or roadside barrier may be shielded with a redirective, non-gating crash cushion with an appropriate width and transition detail. These signs should be designed according to the latest edition of the Sign Support Manual.

Figure 4-43 shows the three permanent ground mounted sign support system types listing acceptable sign materials for each system against sign assembly area ranges for each system.

Many breakaway sign support systems are currently being crash tested according to MASH. MTO standards will be updated as MASH-compliant systems are accepted for use on provincial highways.

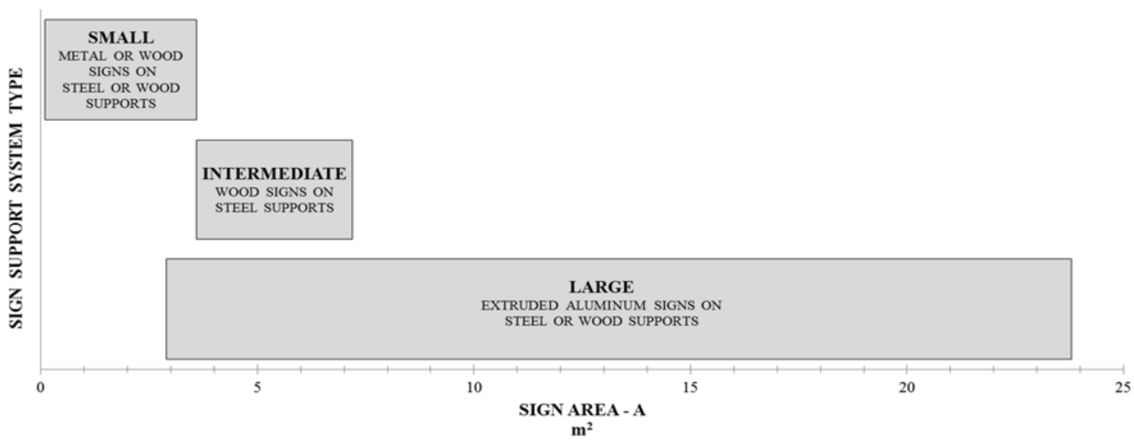


Figure 4-45: Sign Support System Types and Sign Areas

4.5.1 Small Sign Support Systems

Although small signs are not always perceived as particularly hazardous, small signs can cause significant damage to impacting vehicles. Small and intermediate breakaway sign support system standards were developed for various sign sizes typically used on provincial highways. Each standard sign support system met the crash test acceptance requirements of NCHRP Report 350 Test Level 3 and designed for wind speeds of 110 km/h (70 mph), and wind load/pressure requirements for a ten-year return period in Ontario according to the Canadian Highway Bridge Design Code.

NCHRP Report 350 requires the sign support system to fail in a predictable manner when impacted head-on by a small vehicle at 35 km/h and at 100 km/h, and by a pick-up truck at 100 km/h. For acceptance, the crash tested vehicle needs to remain upright during and after the impact with minimal deformation or intrusion into the passenger compartment.

In general, the bottom of the sign needs to be mounted at a minimum height of 2.1m above the ground (measured vertically at each post) to allow errant vehicles to pass under the sign during an impact. As the average passenger vehicle is less than 2.1 m wide, when two or more posts are required for larger sign assemblies, the clearance between them should be 2.1 m or greater to minimize the probability of an errant vehicle of impacting two posts at same time. Support system posts may be located closer together than 2.1 m when they have been crash tested in that configuration as specified in the applicable standards.

Wooden sign support system posts of specified species and grade measuring 89 mm x 89 mm are designed to fracture near ground level during a passenger vehicle impact. Larger wooden posts need to be drilled perpendicular to the roadway at a height of 75 mm and 375 mm above the ground to weaken them in shear to ensure they fracture near ground level while maintaining moment capacity to resist wind loads. Figure 4-44 shows proper orientation of drilled holes that are specified in the applicable standards for small sign support systems with wooden posts.

For wood support systems, 89 mm x 89 mm (nominal 4” x 4”) and drilled 89 mm x 140 mm (nominal 6” x 6”) direct buried non-proprietary pressure treated wood post systems have been successfully crash tested in single and double post configurations. The posts are direct buried a minimum of 920mm or 1200mm into the ground, dependent on size and configuration. For these size posts in double post configurations, they are set no more than 2.1 m apart when measured from outside face of each post as shown in Figure 4-44. For larger drilled 140 mm x 140 mm or drilled 140 mm x 189 mm posts in double post configurations, the horizontal clearance between the posts is minimum 2.1 m (measured inside face to inside face of each post).

Steel sign support system posts are also designed to fracture near ground level during a passenger vehicle impact. The Nucor Rib-Bak high strength steel post uses a proprietary Lap-Splice and bolts to connect their upper sign post and lower stub post at ground level, with the top of lower stub post set no higher than 100 mm above ground. For double or triple post configurations, they are set no more than 2.1 m apart when measured from outside face of each post as shown in Figure 4-45.

The Sqr-Lok perforated square tube small sign support system uses a 57 mm x 57 mm x 1065mm long lower anchor steel post with top set no higher than 100mm above ground. A 63 mm x 63 mm x 450 mm long sleeve is placed over the stub post with top also set no higher than 100 mm above ground. The 52 mm x 52 mm upper post is inserted to a depth of 200 mm inside of the lower anchor posts and sleeve, and then bolted together with the proprietary corner bolt. For double post configurations they are set no more than 2.1 m apart when measured from outside face of each post as shown in Figure 4-45.

All steel support systems are pre-punched with 11mm diameter holes at 50mm centres for mounting of the signs. These holes can also used to jack out existing lower posts during repairs or relocations.

Design Guidance:

Small sign assemblies consist of one or more signs and tabs mounted on a sign support system with specified sign hardware having a total sign or sign board area not greater than 3.6m^2.These signs may be metal or plywood, and installers are given the option to select the appropriate metal or wooden breakaway sign support system for each small sign assembly based on the dimensions and area of the sign assembly. The system may consist of a single, double, or triple post configuration.

On low speed urban roadways with barrier type curb and posted speeds less than 70 km/h, small signs of up to 90 cm wide by 90 cm high and total sign area including tabs not greater than 0.56m^2 may continue to be installed on non-breakaway U-flange post system. Breakaway systems may also be installed on low speed urban roadways.

The ministry specifies different types of sign support systems based on the type of sign material, sign dimensions, and total area of the sign including any tabs. Breakaway sign support systems should be used for all new sign installations on high speed and low speed roadways within provincial highway right-of-ways unless located behind an appropriate length of existing barrier. New barriers should not be installed or extended for the sole purpose of protecting a new sign assembly on non-breakaway sign supports.

In general all sign installations are intended for installation on traversable roadsides with sideslopes 3H:1V or flatter. Posts should be offset more than 1.5m from bottom of drainage ditches, and when installed behind barrier should be offset beyond the working width of the barrier system. Sign installations should not be installed within the 22m x 6m obstacle clear area beyond guide rail terminal systems.

Sign installations are intended for installation in competent soils of uniform composition. Site foundation conditions requiring a modification to the design or use of another sign support system include:

- Rock cut
- Rock fills
- Soil is exceptionally soft or loose.

Small signs can measure up to 2.4m wide and up to 1.5m high, with a maximum area up to 3.6 m^2. For durability, different combinations and sizes of breakaway pressure treated wooden and hot dipped galvanized steel sign support system standards have been developed for various sign sizes typically used on provincial highways. Installers have the option to select the appropriate wooden and/or steel sign support system standard for each sign installation dependent upon sign dimensions and sign area.

General details and dimensions for Permanent Ground Mounted Small Sign Support Systems with single and double wooden post configurations or with single, double or triple steel post configurations can be found in the applicable standards active in MTO’s Contract Preparation System.

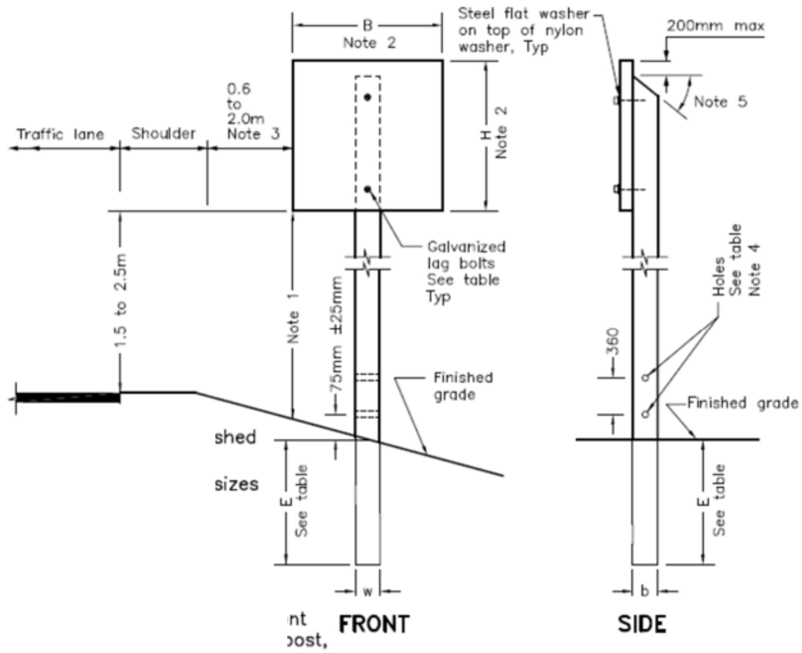


Figure 4-46: Small Breakaway Single Post System with 89 mm x 140 mm Drilled Wooden Post

See applicable standards for other post configurations and note references

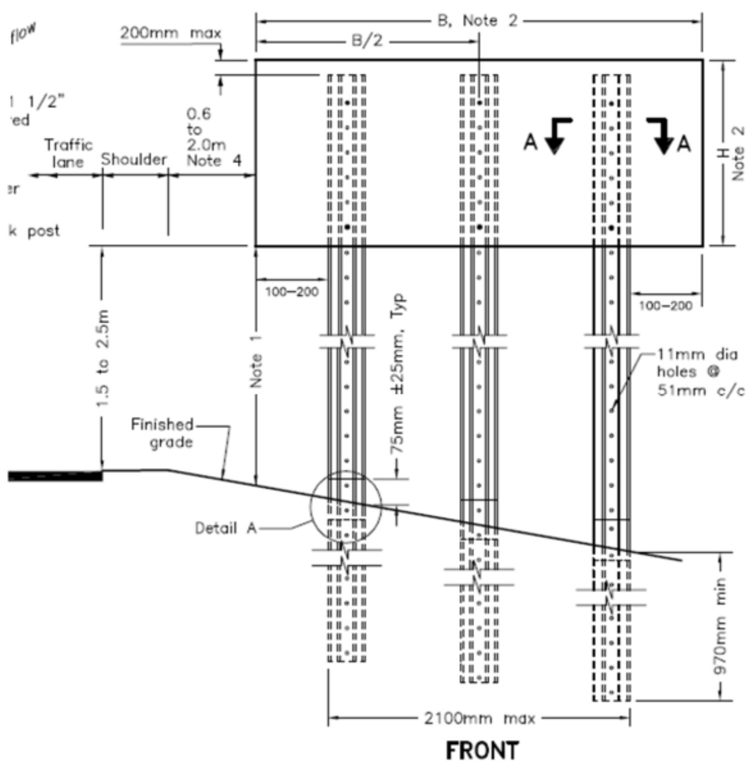


Figure 4-47: Small Breakaway Triple Post System with Rib-Bak Steel Posts

See applicable standards for other post configurations and note references.

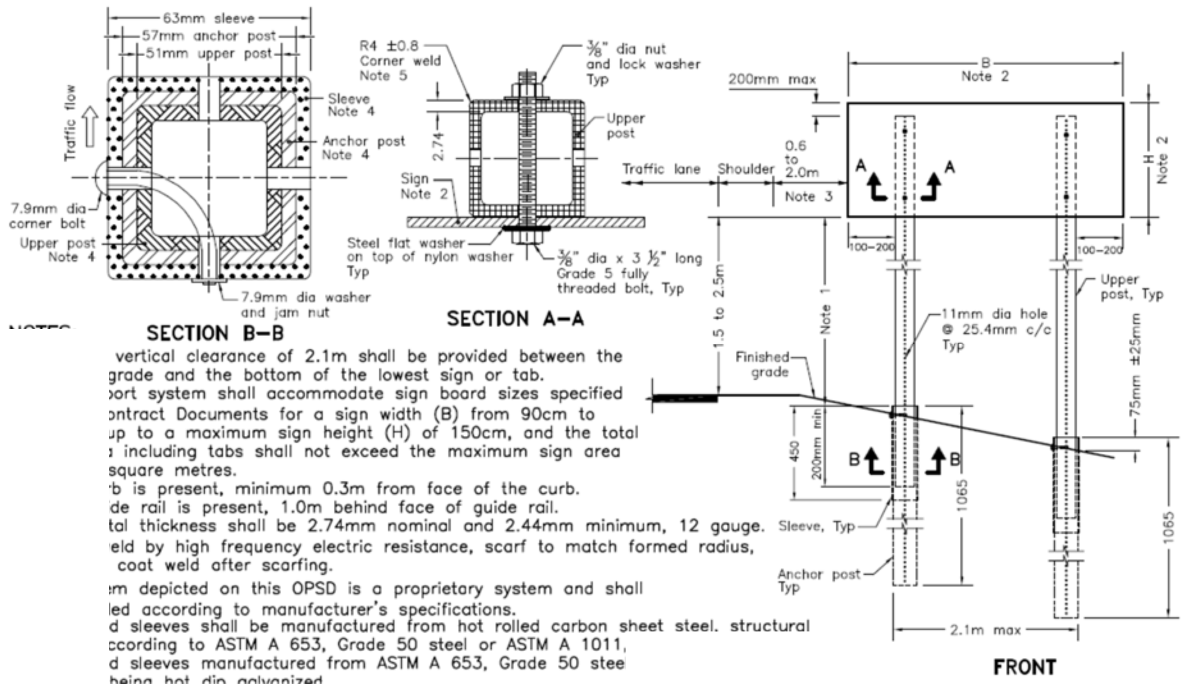


Figure 4-48: Small Breakaway Double Post System with Sqr-Loc Steel Posts

See applicable standards for other post configurations and note references.

4.5.2 Intermediate Sign Support Systems

Intermediate sign assemblies consist of one or more signs and tabs mounted on a sign support system with specified sign hardware having a width not greater than 2.4 m, a height not greater than 3.0 m, and a total sign or sign board area not greater than 7.2 m². These plywood signs are installed on the two-post steel breakaway Slip-Safe Supreme system from Nucor Steel Marion, Inc. and do not require concrete footings. The Slip-Safe Supreme system can be installed and repaired quickly, easily and cost effectively as design and placement of concrete footings are not required.

The Slip-Safe Supreme™ is a propriety system developed by Nucor Marion Steel, Inc. This system meets the crash test acceptance requirements of NCHRP Report 350, Test Level 3. This is an alternative option for a multi-panel (in height) plywood signs of up to 3.0 m high and up to 2.4 m wide with a maximum area of 7.2 m². It is acceptable to install small 2.4 m wide wood sign assemblies with areas less than 3.6 m^2 on intermediate sign support systems when specified. At this time, aluminum extruded signs shall not be installed on the Slip-Safe Supreme system.

The Slip-Safe Supreme system provides a solution for taller plywood signs of up to 3.0 m high and up to 2.4 m wide with a maximum area of 7.2 m². While 2.4 m wide small signs with heights less than 1.5 m and areas less than 3.6m^2 may be installed on intermediate sign support system, it is generally more economical to install small signs on a small sign support system.

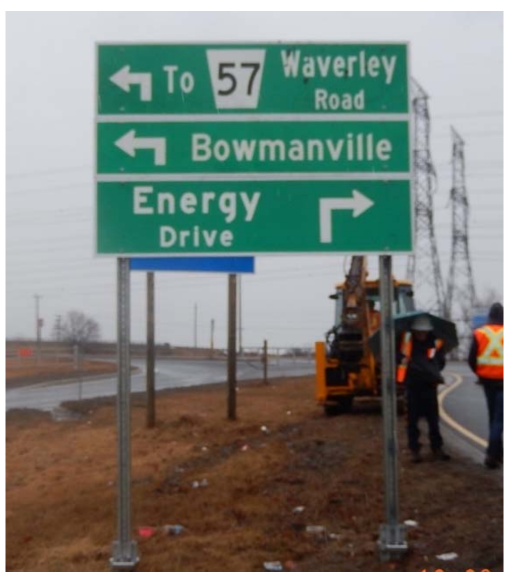


Figure 4-49: SlipSafe Supreme Intermediate Sign Support System Installation

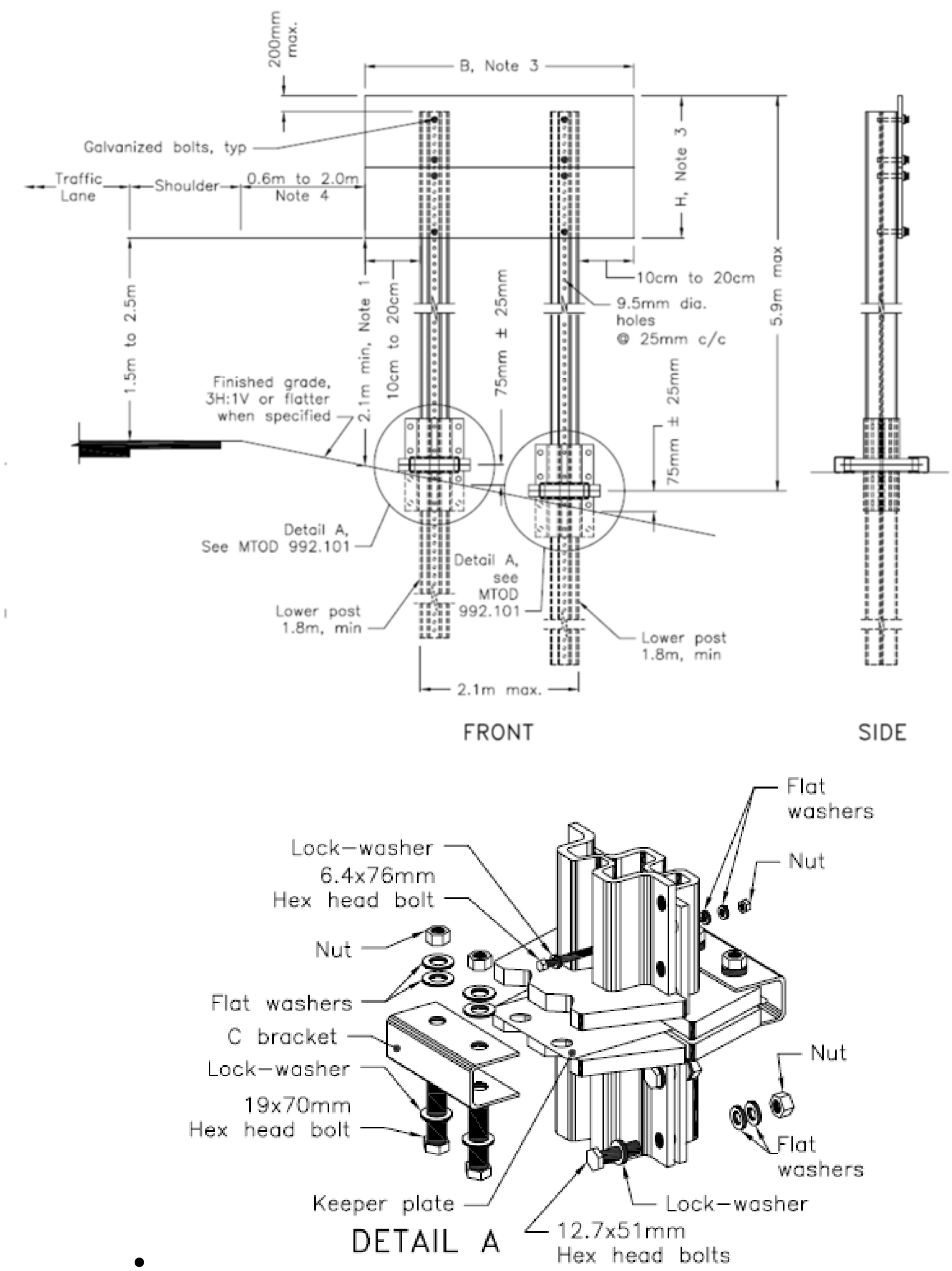


Figure 4-50: Breakaway Component Details

See applicable standard for other details and note references

4.5.3 Sign Supports on Concrete Median Barrier

The sliding base and chute median sign support is a non-propriety system developed by Texas Transportation Institution for the Texas Department of Transportation. This system meets the crash test acceptance requirements of MASH Test Level 3. The system consists of a slide assembly which is anchored to the top of the concrete barrier. A collar is placed in the slide assembly which supports a pipe to which the sign board is attached. When impacted by a vehicle from either direction the collar and sign support assembly slides towards the end of the chute where it is stopped by the anchors. The sign support deforms but does not break away and allows for safe containment and redirection of the vehicle.

This design may be used for signs between 60 and 90 cm wide by 150 cm high and not exceeding 1.35 m^2 in total area. The sliding chute base requires a minimum barrier top width of 200 mm. There is not currently any crash tested designs available for barriers with less than 200 mm top width however a non-tested wooden post with steel plate system is available for use on flared concrete median barriers with a minimum top width of 1.0 m.

Figure 4-51: Sliding Base and Chute Median Sign Support System Installation

4.6 Ramp Closure Gates

Since about 2009, most new ramp closure gates installed on provincial highway capital construction contracts should have been breakaway when stored in the ramp open position (gate parallel to traffic). The breakaway ramp closure gate implemented by MTO is considered equivalent to the South Dakota DOT gate that was developed and crash tested by MwRSF in 1995 to meet the crash test acceptance requirements of NCHRP Report 350 TL-3. The gates are manufactured from 50 mm x 50 mm square aluminium tubing and are available in standard 9 m and 12 m lengths. Proprietary breakaway double neck Transpo Pole-Safe couplers are used to attache the aluminium gate to the concrete footing. Gates should be installed adjacent to the right shoulder on the ramp as specified on the MTO standards. Figure 4-50 shows the standard installation for a single lane 9 m entrance ramp from an arterial road to a freeway. Standard sign layouts are available for attachment of required signs to the gate and support post.

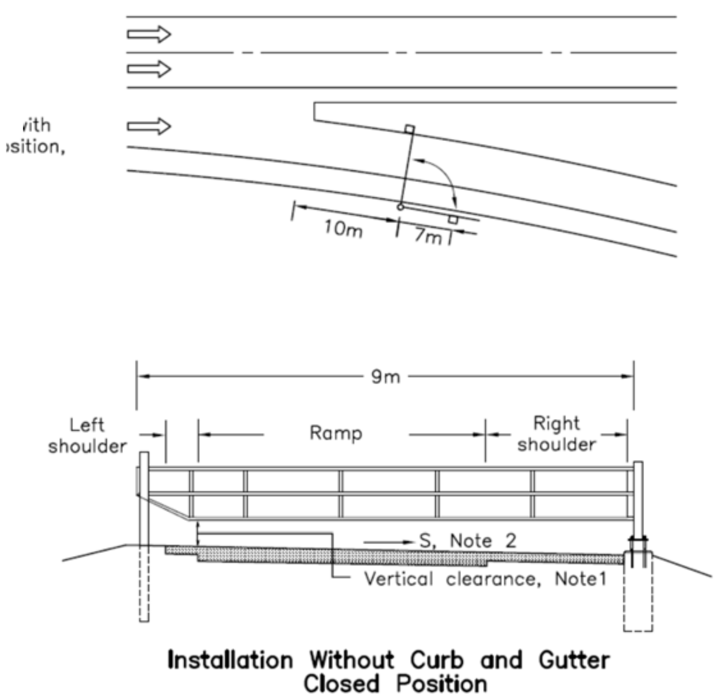


Figure 4-52: Breakaway Ramp Closure Gate Installed on Ramp Without Curb. Gate shown in ramp closed position.

4.7 Culvert Ends

Exposed crossing culvert ends projecting beyond foreslopes within the desirable clear zone along roadways are considered to be obstacles with high severity indices. Figure Figure 4-51 shows an exposed culvert end. Errant vehicles encroaching onto recoverable slopes and non-recoverable slopes can come to abrupt stops or rollover when encountering exposed crossing culvert ends or parallel culvert ends. Various grading design and safety end treatment alternatives are available to minimize probability of impacts by locating culvert ends beyond the desirable clear zone or modifying ends to make them traversable. These options should be considered and evaluated early during hydraulic design of culverts prior to finalizing the length of new culverts and culvert extensions to determine if alternative grading options and safety end treatments can result in a cost beneficial design without having to specify a barrier system to shield the culvert end.

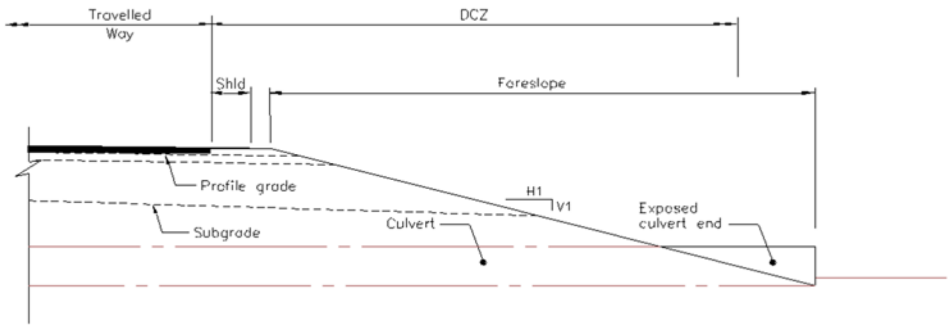
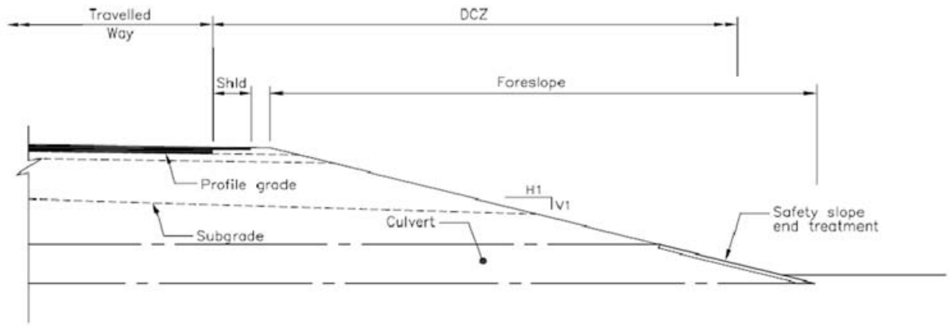
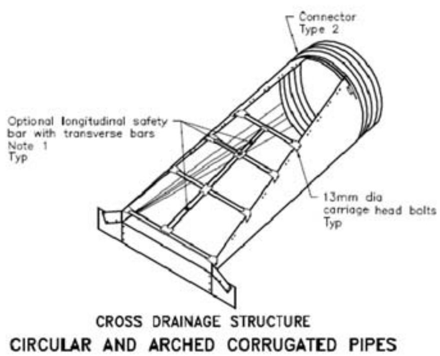


Figure 4-53: Exposed Culvert End within Desirable Clear Zone

Steel safety slope end treatments that match 4H:1V and 6H:1V foreslopes as shown in Figure 4-52 are available for round culverts ranging in size from 300 mm to 1400 mm diameters, arched pipes up to 2130 mm spans with 1400 mm rise, and elliptical pipes up to 1930 mm spans with 1220 rise. For cross culverts with openings wider than 750 mm, longitudinal safety bars should be used. For parallel culverts, transverse bars should be used. Heavier longitudinal bars are used for concrete box culverts.

Another option is to use a headwall beyond the desirable clear zone and adjust the foreslope as shown in Figure 4-53. While this option results in a vertical drop off over top of the culvert and headwall, the safety benefits of the increased offset to the headwall versus an exposed end versus a relatively long barrier system in proximity to roadway needs to be analysed as part of a benefit cost evaluation.





Concrete Box Culvert

Figure 4-54: Culvert End with Safety Slope End Treatment

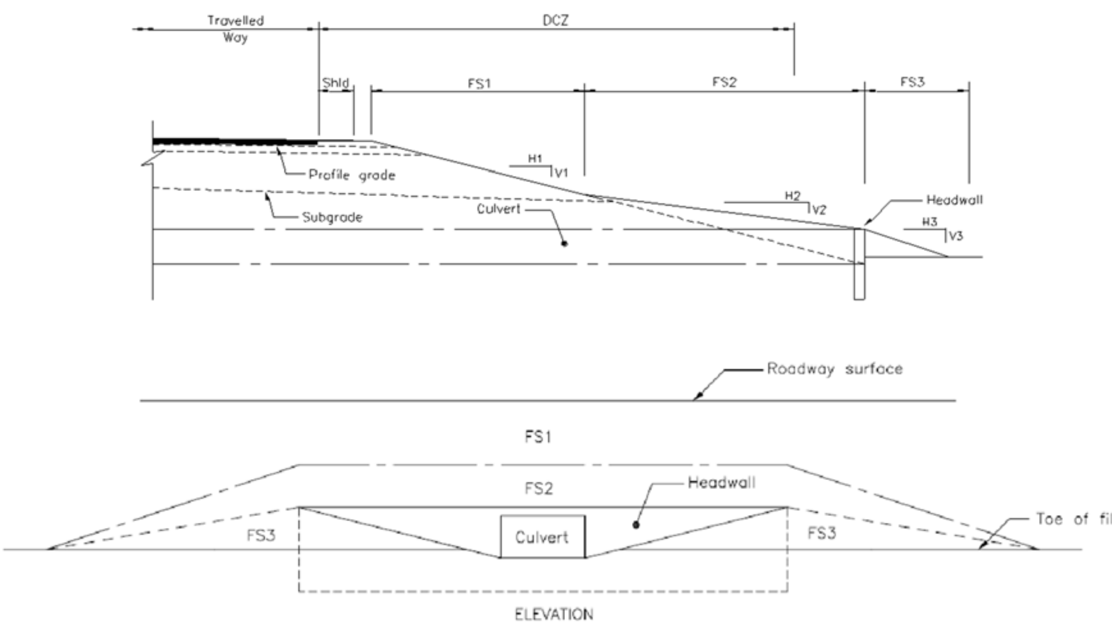


Figure 4-55: Culvert End with Headwall

5. Roadside Safety Hardware for Work Zones

For construction work zones where it has been determined that temporary barrier systems are required to provide positive protection between vehicular traffic and the work area and workers, this chapter lists, describes, and provides design guidance for installation of acceptable temporary barrier systems for use on provincial highway projects. Installation and use of these temporary systems also need to comply with guidance provided in OTM Book 7 and according to the Ontario Occupational Health and Safety Act. Temporary barrier systems are also used to separate opposing directions of traffic in detours within work zones.

The work zone systems listed in this chapter are complete as of the time of issue of this manual. New systems are often accepted for use on provincial highways between publications of the manual and designers are encouraged to keep informed of the most current version of all standards specifications, special provisions, standard drawings and policy memoranda pertaining to work zone hardware.

5.1 Temporary Barrier System Performance

The performance of temporary barrier systems is dependent on the design, installation, maintenance, and post-impact repair. Associated grading and appropriate terminals, leaving ends, or anchorage requirements, should be provided for each specific temporary barrier system in order for the barrier system to perform as designed and crash tested.

In order to be effective, a temporary barrier system should be capable of restraining a selected design vehicle under specified impact conditions (design vehicle of a particular size range, at a given speed and angle of impact). A temporary barrier system should prevent the selected design vehicle from the following:

- penetrating,
- vaulting over (over-riding), or
- wedging under (under-riding) the installation.

Unless otherwise designed, the temporary barrier system should remain substantially intact so that system elements and debris will not pose an undue risk to occupants in the impacting vehicle, other traffic, and workers in the work area. The temporary barrier system should be designed and installed to reduce the risk of spearing an impacting vehicle. A vehicle-barrier system collision should result in redirection of the impacting vehicle at a low departure angle that will minimize the risk of interacting with other vehicles. Finally, the collision should not result in excessive lateral or longitudinal deceleration of the vehicle's occupants.

Temporary construction barrier (TCB) systems, should be of sufficient length and be properly terminated and anchored. In the case of freestanding TCB systems (e.g., no restraint system), sufficient length, and mass are necessary to prevent the system from being displaced significantly upon impact.

Since the dynamics of a collision are complex, the most effective means of assessing barrier system performance is through full-scale crash testing. By standardizing such tests, barrier system designers can compare the relative safety performance of alternative systems. As noted elsewhere in this manual, MTO has started to implement installations of new temporary and permanent roadside safety hardware on provincial highways that meets the crash test and evaluation criteria contained in the AASHTO Manual for Assessing Safety Hardware (MASH (2009 or 2016)).

Dynamic deflection is the maximum distance that the barrier system is expected to deflect laterally under a specified design impact, measured from the traffic face of the system. Working width is the distance between the traffic face of the system before impact in accordance with a specified crash test and the maximum lateral position of any major part of the system or vehicle after the crash test.

Temporary construction barriers should be installed, maintained, and inspected to ensure their condition reflects the as-tested configuration and adheres to manufacturer's requirements. Failure to comply with the nature in which these systems were tested can result in failure which could lead to serious injury or fatality of vehicle occupants.

Installation, maintenance and inspection of temporary construction barriers should be performed by persons with manufacturer-accredited training in these activities.

5.1.1 Temporary Construction Barrier Systems

Temporary barrier systems are devices that provide a physical limitation through which a vehicle would not normally pass (O-Reg 213/91, s. 67 (1)). In 2008, MTO implemented and started to phase in acceptance of alternative temporary concrete barrier systems and restraint systems that met the crash test acceptance requirements of NCHRP Report 350 TL-3. In 2013, MTO discontinued acceptance of Type I (I-Lock) temporary concrete barrier on new provincial highway contracts for installations on high speed roadways with posted speeds of 70 km/h and greater and in 2019 it was discontinued for all provincial highway contracts. Type I temporary concrete barrier had been used on MTO projects since the late 1980s when it was implemented to replace temporary concrete barrier with concrete keys or single hook connections. Starting in 2010, MTO started to implement and phase in TCB systems that met MASH TL-3.

Temporary barrier systems are designed and crash tested for use in construction work zones to provide physical separation between motorists and certain long term work zone operations and workers. There are four types of temporary barrier system that have been used successfully on provincial highway projects:

- Temporary Concrete Barrier;
- Moveable Temporary Concrete Barrier;
- Temporary Steel Barrier; and
- Temporary Type M Steel Beam Guide Rail.

To date on most provincial highway projects across the province, TCB systems have been specified and installed in work zones on paved surfaces. TCB is usually used on multi-staged projects where they are subsequently relocated elsewhere within the project for other construction stages. On some recent projects, temporary Type M Steel Beam Guide Rail (SBGR) systems have been used for installations on granular roadway surfaces. On several projects, Temporary Type M SBGR was specified for the first stage, and subsequently removed, salvaged, and reinstalled for a subsequent stage, and then finally, removed, salvaged and reinstalled as part of the permanent roadside barrier system on the project.

Temporary barrier systems are usually owned by the contractor and used in temporary work zones to separate vehicular traffic from work areas and workers. In certain constrained work zones and work operations, movable temporary concrete barrier systems may be advantageous for daily adjustments to the width of the travelled way (number of traffic lanes open to traffic) and the width of the work zone and offset to work zone operations.

Dynamic deflection is an important consideration when selecting the appropriate type of temporary barrier system. Barrier mass, length and connection type affect the performance of the system including dynamic deflection of the system during vehicular impacts.

Considerations such as speed of deployment and ease of relocation may play a significant part in the selection of the type of temporary barrier system best suited for a particular work zone and work zone operation to a particular application.

In May 2019, MTO updated the terminology to Temporary Construction Barrier (TCB) to allow for MASH tested Temporary Steel Barrier systems to be used at the option of the contractor on ministry contracts.

Four categories of Temporary Construction Barrier corresponding to the TL-3 dynamic deflection of each system are created as follows, and correspond to four tender items:

Category I: >1,500 mm

Category II: 1000 mm – 1500 mm

Category III: 500 mm – 999 mm

Category IV: <499 mm

The category that a barrier falls under is indicated in the construction specification and informs the contractor of the available choices for a given tender item. Barriers that satisfy a higher performance category may be used in lieu of a specified lower performance system, allowing greater on-site flexibility.

Designers are required to be aware of the distance from the edge of shoulder to the top of an excavation or to fixed objects such as bridge parapets, roadway protection or scaffolding when specifying a Temporary Construction Barrier item.

The creation of the deflection category system simplifies the process for adding or updating temporary barrier systems as a new system may simply be added to the list of available systems in the existing specification and categorized appropriately.
Designers shall only use temporary construction barriers listed in active specifications or special provisions and standard drawings, or those for which such documents have been issued by the Highway Design Office on a contract-specific basis. This requirement applies to all design-bid-build, design-build, P3, CMCG and all other alternative delivery model contracts. This requirement also applies to use of temporary construction barrier on municipal roads crossing provincial highways either at-grade or grade-separated.

Systems shall not be modified from the configurations shown in the standards. Highway Design Office shall be contacted for guidance in case site-specific constraints preclude the use of work zone hardware in its standard configuration.

5.1.1.1 Use of TCB's to Separate Opposing Traffic Flows

Many staged freeway construction contracts involve the temporary shifting of a narrow median centreline or the temporary reduction of traffic from two lanes in each direction on two separate platforms to one lane in each direction on a single platform through the construction of temporary median crossovers. In many cases, the use of temporary construction barriers to separate the two directions of high-speed, high-volume traffic provides a tangible safety benefit.

Desirably, a barrier should be provided such that the dynamic deflection is less than the offset of the traffic face of the barrier to the oncoming lane being protected.

It may not be absolutely necessary in all cases to provide a barrier that will not deflect into the adjacent oncoming lane based on its TL-3 working width. This is particularly true in cases where a barrier is used to separate parallel opposing single lanes of traffic as the odds of an impact with a speed and angle combination resembling those seen in crash testing are significantly diminished. Additional mitigating factors are the fact that vehicles don't occupy the entire width of a lane and drivers tend to keep a distance from barriers when driving parallel to them (see discussion on shy line in section 3.1.6). The use of a high-performance barrier such as Category IV may require the use of anchors which can add significant cost and construction time for what may be only marginal safety improvements.

At a minimum, in the context of the above consideration, a barrier one deflection category lower may be considered where they are used to separate single opposing lanes of traffic.

TL-5 temporary barrier should desirably be used when separating multiple adjacent opposing through lanes (3 or more in one or both directions) as impact speed and angle combinations may be higher. TL-3 Category IV barriers should be used as a minimum in these instances.

Where traffic volumes are sufficiently low, delineation using pavement markings and delineator posts may also be considered as a means of separating temporary opposing single-lane traffic flows.

A degree of designer judgement is encouraged when considering the use of TCB's to separate opposing traffic flows during construction. Highway Design Office may be contacted during design of such installations for additional guidance.

Where restrained barriers are used to separate opposing flows of traffic, those with symmetrical restraint configurations must be used. Barriers with anchors only on the traffic side are only crash tested for impacts on that side and may not perform predictably if impacted on the non-pinned side.

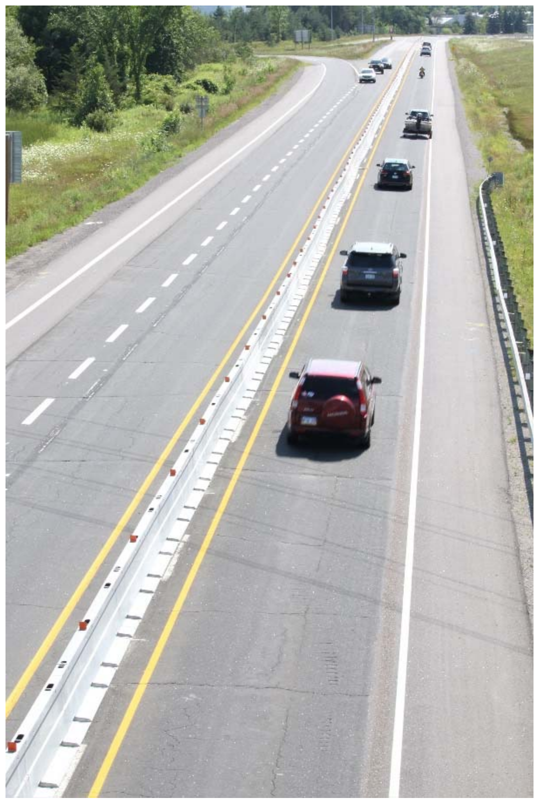


Figure 5-1: Category IV Barrier Separating Staged Opposing Freeway Traffic

5.1.2 Temporary Concrete Barrier Systems

The following temporary barrier systems are accepted for use on provincial highway projects according to applicable standards active in the Contract Preparation System:

- Type J;
- Type M;
- Type T;
- Type X
- Type Z; and
- ReBloc TL-5

Temporary Concrete Barrier is a portable barrier system consisting of free-standing precast concrete segments that are positively connected together to form a continuous barrier system. Descriptions of the various types of TCB systems accepted for use and specified on provincial highway projects are described in this chapter.

In 2008, the ministry implemented two new temporary concrete barrier designs that met the crash test acceptance requirements of NCHRP Report 350 at TL-3. This included temporary concrete barriers with Type J and Type M connections.

In 2008 it was also announced that temporary concrete barrier with I-Lock connections will be discontinued on ministry contracts awarded after December 13, 2013 for installations on high speed roadways. The ministry also agreed in 2008 to continue to accept I-Lock temporary concrete barrier on low speed roadways with posted speeds less than 70 km/h. I-lock barrier was removed from the ministry’s specification after the conversion to Temporary Construction Barrier.

In 2010, MTO began to specify temporary concrete barrier with Type T connections which met NCHRP Report 350 TL-3. In 2010, the Type T temporary concrete barrier design was modified and then successfully crash tested in accordance with MASH TL-3.

In 2015, MTO started to specify Type X temporary concrete barrier for use on bridge decks where minimal deflection was required and bolting into the bridge deck was not acceptable. Currently Type X temporary concrete barrier is the only unrestrained concrete or steel system that is acceptable for Category III.

Each installation of temporary concrete barrier less than 100 m in length should consist of units having the same type of temporary concrete barrier connection. For installations longer than 100 m in length, it is acceptable to transition from one type of temporary concrete barrier connection to another type of temporary concrete barrier connection by use of a thrie beam rail connections across the front and back side of the barrier connections.

There are not currently standards for transitions between temporary concrete barrier and temporary steel barrier or between two different temporary steel barrier systems. Highway Design Office should be contacted if such connections are proposed.

Precast Ontario Tall Wall barrier segments with I-Lock connections should not be used as a temporary concrete barrier on construction sites. These barriers have not been crash tested in a freestanding configuration and are not compatible with standard temporary crash cushions.

Advantages and Disadvantages:

The advantages of temporary concrete barrier are:

- Cost of installation is relatively inexpensive compared to other temporary barrier systems;
- Can be used on horizontal curves with radius of 45 m or greater; and
- Can be connected to permanent concrete barriers and concrete bridge rails.

The disadvantages of temporary concrete barrier are:

- Size and mass make them expensive for remote locations;
- Heavy to move, transport and unload at work site; and
- Need to be placed on paved surfaces.

5.1.2.1 Type J Temporary Concrete Barrier:

Type J TCB is a proprietary precast concrete barrier developed by Easi-Set Industries Inc. using patented J-J hook connections that meets MASH TL-3. The version precast in Ontario has a New Jersey shape that is identical in shape to the I-Lock TCB except that the lower vertical face has been increased in height to 75 mm. The height of the Type J temporary concrete barrier is 900 mm, with a width of 630 mm at the bottom and 165 mm at the top. The standard lengths being produced in Ontario are 4m and 6m. Adjacent segments are connected together by the steel J-J hooks that are cast into the ends of each segment. The J-J hooks slide together to form a positive connection. The system may be installed on horizontal curves with radii as sharp as 31 m with the 4 m units, and 47 m with the 6 m units. Additional details are provided in Figure 5-2.

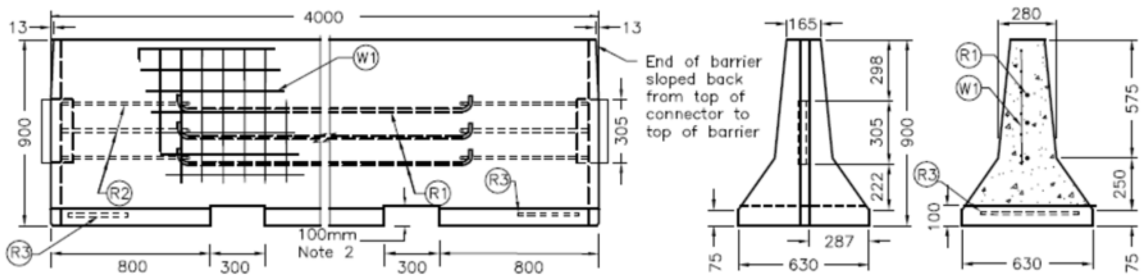


Figure 5-2: Type J Temporary Concrete Barrier

5.1.2.2 Type M Temporary Concrete Barrier:

Type M temporary concrete barrier is a non-proprietary precast concrete barrier that was developed by Midwest Roadside Safety Facility (MwRSF) that meets MASH TL-3. It has a modified safety shape design with a height of 815 mm, width of 585mm at the bottom and 205mm at the top. The standard length being produced in Ontario is 3805 mm with 92mm gaps between each barrier unit for the pin and loop connections, resulting in an effective length of 3897mm. Connections consist of a 32mm diameter A36 steel pin placed down through six steel loops (three per side). Type M temporary concrete barrier anchored to concrete pavement or bridge decks has been successfully crash tested according to MASH. The restrained system was crash tested at a particular offset to a vertical drop off. When impacted, the restrained barriers cantilevered over the edge but were still able to contain and redirect the impacting vehicle. As such, minimum offsets to excavation edges are different than minimum offsets to obstacles on standard drawings. The system may be installed on horizontal curves with radii as sharp as 26 m. Additional details are provided in Figure 5-3. Restraint system details are provided on the applicable standards active in MTO’s Contract Preparation System.

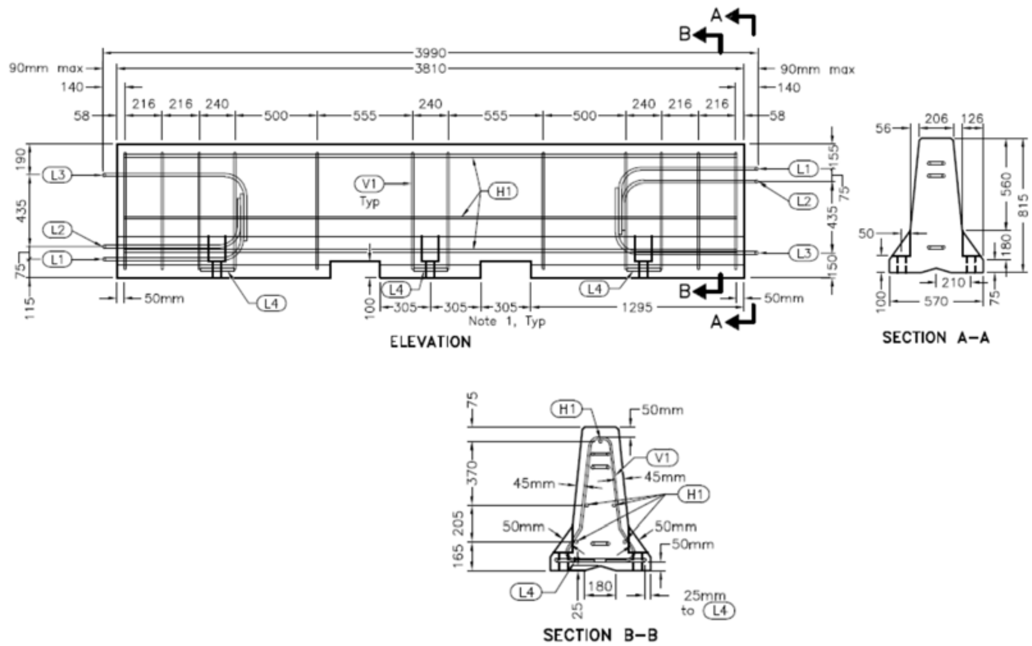


Figure 5-3: Type M Temporary Concrete Barrier

5.1.2.3 Type T Temporary Concrete Barrier:

Type T temporary concrete barrier is a proprietary barrier that was developed by Rockingham Precast Ltd. that meets MASH TL-3. It is an F-shape design with a height of 815 mm, width of 600 mm at the bottom and 230 mm at the top. The standard lengths being produced in Ontario are 4 m and 6 m. One end of each unit has a steel T-shape plate cast into one end of the barrier, and the opposite end has a slotted steel tube cast into the concrete. Connecting the barrier segments involves lowering units successively into place with the connections between the adjoining barriers engaged, forming a continuous wall. The system may be installed on horizontal curves with radii as sharp as 26 m with the 4 m units, and 39 m with the 6 m units. Additional details are provided in Figure 5-4.

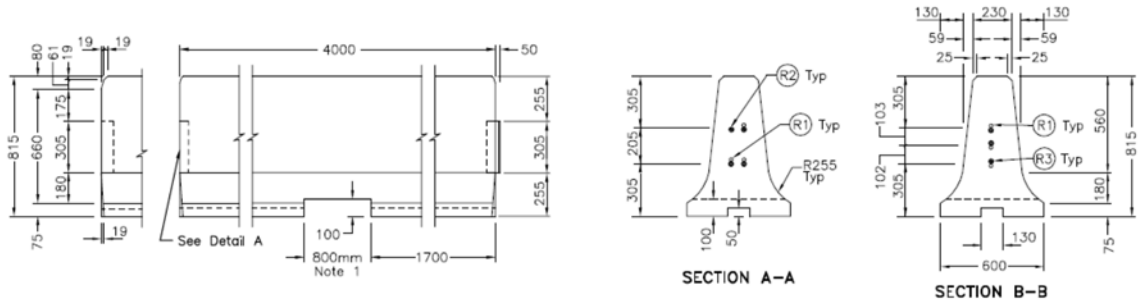


Figure 5-4: Type T Temporary Concrete Barrier

5.1.2.4 Type X Temporary Concrete Barrier:

Type X temporary concrete barrier is a non-proprietary precast concrete barrier that was developed by the Texas Transportation Institute (TTI) for Texas Department of Transportation that meets NCHRP Report 350 TL-3 and MASH TL-3. It has a F-shape design with a height of 815 mm, width of 600 mm at the bottom and 235 mm at the top. The standard lengths being produced in Ontario are 3 m, 6 m, and 9 m. Connections consist of two 22.2 mm diameter Grade B7 threaded cross bolts at each end. The system was developed for constrained work zones where minimal dynamic deflection was desired. The 3 m version when crash tested according to MASH TL-3 (60 m installation length) reported 686 mm maximum dynamic deflection. The system may be installed on horizontal curves with radii as sharp as 38.1 m for 3 m units, and 122 m for 9 m units. Additional details are provided in Figure 5-5.

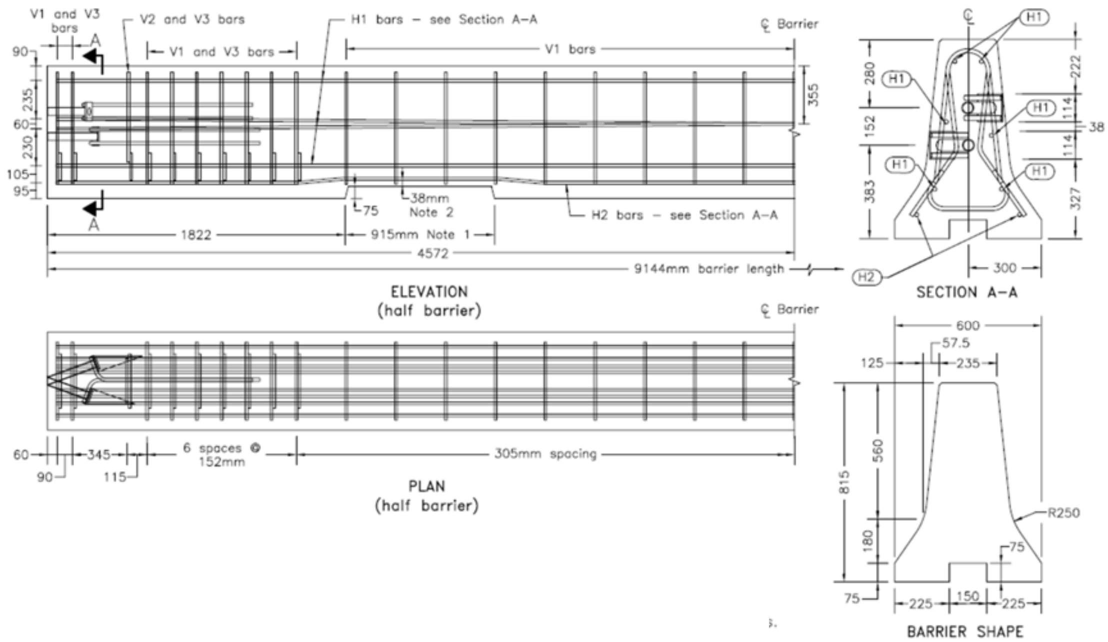


Figure 5-5: Type X Temporary Concrete Barrier

Type X barrier may also be anchored. Anchoring of Type X barrier requires the use of 4 m barrier units with three recesses cast into the lower portion to allow for anchors to be installed into the pavement. All other aspects of the barrier are identical to the unrestrained versions. Restrained Type X requires the use of a proprietary ReDD insert placed into the recesses, through which the anchor is placed. Restrained Type X barrier is high performing system, with a MASH TL-3 dynamic deflection of 50 mm. Anchors are placed on only one side of the barrier which makes this variation unsuitable for separation of opposing traffic flows.

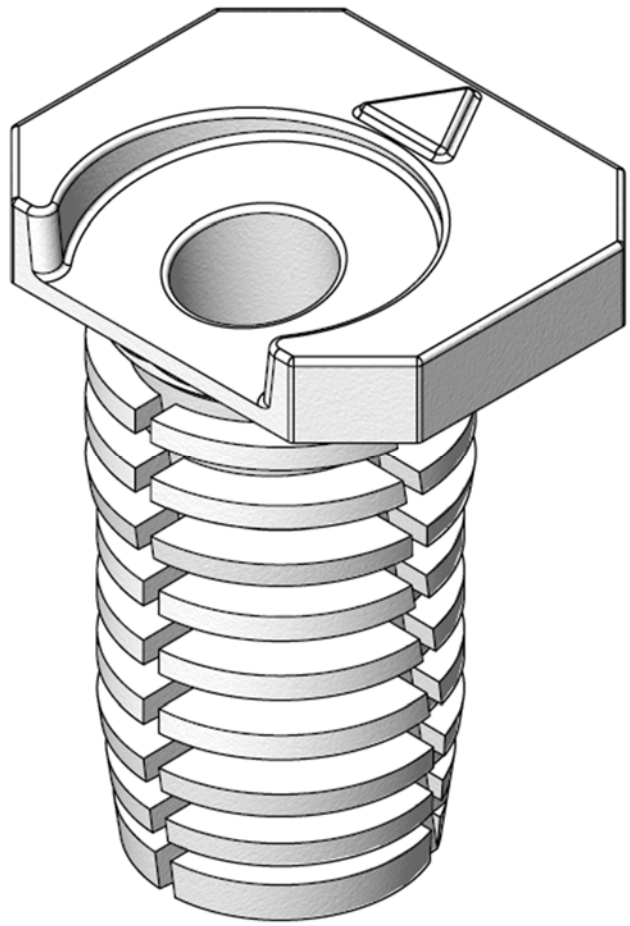


Figure 5-6: ReDD Insert for Type X Barrier

5.1.2.5 Type Z Temporary Concrete Barrier:

Type Z temporary concrete barrier stands for ZoneBloc - A proprietary narrow profile concrete barrier distributed by Hill & Smith Inc. The concrete longitudinal barrier system has been crash tested to AASHTO MASH TL-3. It has a cross section similar to an I-Beam with a height of 800 mm, width of 300 mm at the bottom, 180 mm at the top, and between 90 and 75 mm in the middle section. The system consists of 12m standard ZoneBloc barrier sections along with anchored terminal barrier at the approach and leaving ends of the installation. The ZoneBloc anchored terminal barrier allow transitioning from crash cushion to ZoneBloc, providing bidirectional approach and leaving ends If required. The barriers are connecting with proprietary tension links that result in a 1150 mm dynamic deflection when tested to MASH TL-3. Connecting the barrier segments involves lowering units successively into place with the connections between adjoining barriers engaged, forming a continuous wall. The barrier rest on rubber pads to minimize damage to the road surface. The system may be installed on horizontal curves with radii as sharp as 260 m.

The Zonebloc's narrow base width of only 300 mm allows the longitudinal barrier system to have a narrow overall working width that is ideal for constrained work zones. Type Z Barrier has similar deflection characteristics to standard temporary concrete barrier, but with half the average barrier width.

Type Z barrier may also be restrained. Restrained Type Z barrier uses the same 12 m barrier unit length as the unrestrained version with the exception of eight recesses cast into the lower portion to allow for anchors to be installed into the pavement. The restrained Type Z is a very high-performance barrier with a MASH TL-3 dynamic deflection of approximately 300 mm. Anchoring is symmetrical which allows for this barrier to be used to separate opposing traffic flows.

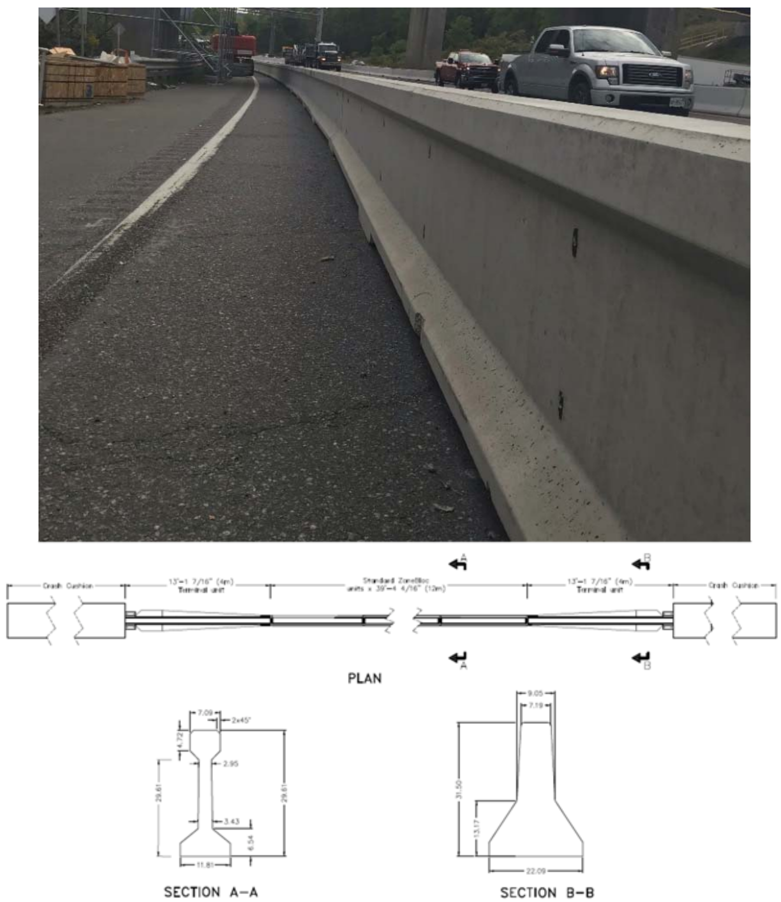


Figure 5-7: Type Z Temporary Concrete Barrier

Manufacturer: Hill and Smith
Website: https://hillandsmith.com/products/zonebloc

5.1.3 Movable Temporary Concrete Barrier System

Where temporary barriers are required and lane closures are restricted to specific times of day, Movable Temporary Concrete Barrier (MTCB) should be used.

5.1.3.1 Quickchange Moveable Barrier

The Quickchange Moveable Barrier (QMB) System is a proprietary movable temporary concrete barrier system that meets NCHRP Report 350 TL-3. The system consists of one metre long free-standing, heavily reinforced, precast concrete barrier segments that compatible with specialized barrier transfer machine as shown in Figure 5-8. The connected barrier segments can be shifted laterally by one lane-width in a single pass of the equipment.

Figure 5-8: Quickchange Moveable Barrier Transfer Machine Shifting QMB Barrier

The QMB concrete segments are heavily steel reinforced and measure 815 mm tall by 610 mm wide, and 1.0 m in length with a steel hinge connection. Additional details are provided in Figure 5-9.

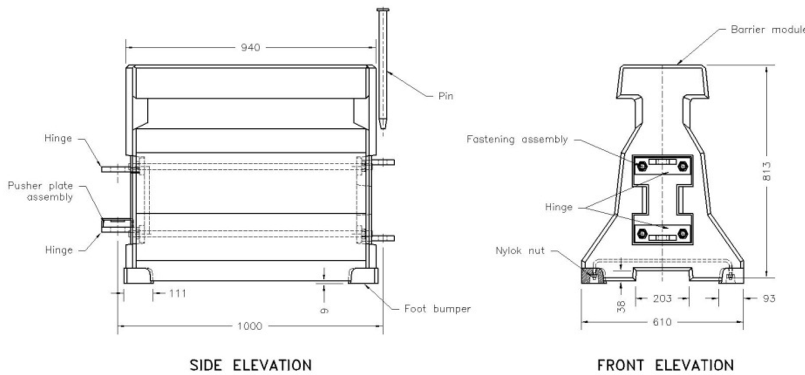


Figure 5-9: Quickchange Movable Barrier System

Manufacturer: Lindsay Corporation – Barrier Systems Inc.
Web Site: http://www.barriersystemsinc.com/

5.1.3.2 Reactive Tension System

The Reactive Tension System (RTS) is a proprietary movable temporary concrete barrier system that meets MASH TL-3. The system consists of one metre long free-standing, reinforced, precast concrete barrier segments that compatible with specialized barrier transfer machine as shown in Figure 5-10. The connected barrier segments can be shifted laterally by one lane-width in a single pass of the equipment.

Figure 5-10: Reactive Tension System Barrier
Photo Courtesy of Lindsay Transportation

The RTS concrete segments are steel reinforced and measure 822 mm tall by 457 mm wide, and 940 m in length with a steel hinge connection. Additional details are provided in Figure 5-11.

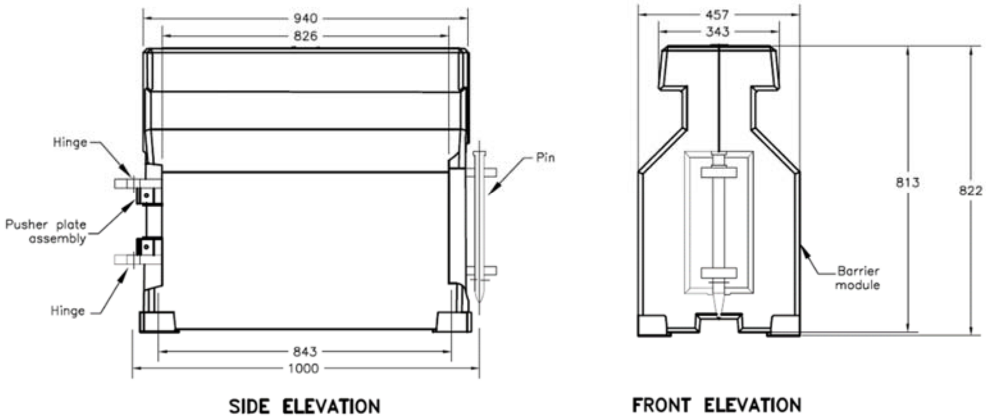


Figure 5-11: Reactive Tension System

Manufacturer: Lindsay Corporation
Web Site: http://www.lindsay.com

5.1.3.3 Flux Barrier

The FLUX barrier is a proprietary movable temporary concrete barrier system that meets MASH TL-3. The system consists of one metre long free-standing, heavily reinforced, precast concrete barrier segments that compatible with specialized barrier transfer machine as shown in Figure 5-12. The connected barrier segments can be shifted laterally by one lane-width in a single pass of the equipment.

Figure 5-12: FLUX barrier

The FLUX barrier segments are heavily steel reinforced and measure 864 mm tall by 457 mm wide, and 1.0 m in length with a steel hinge connection. Additional details are provided in Figure 5-13.

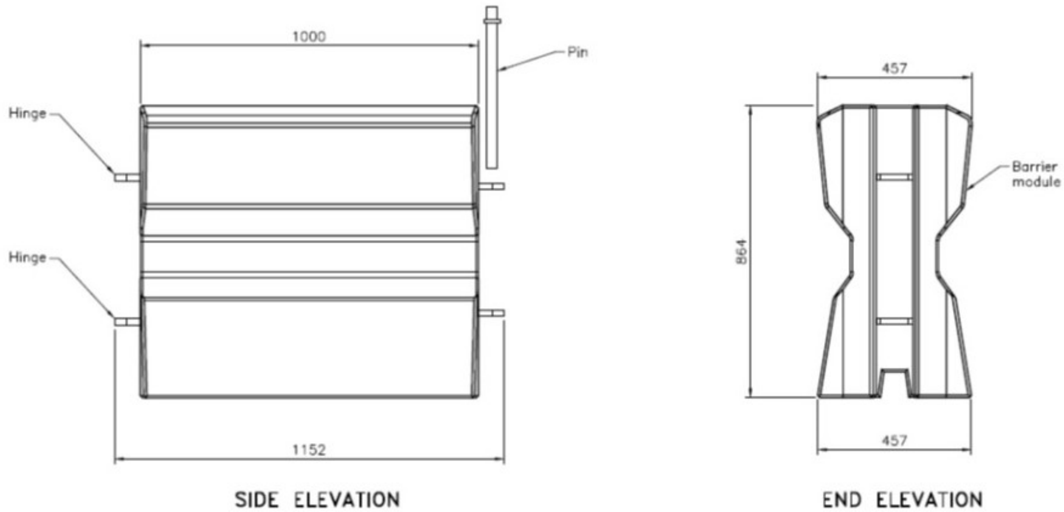


Figure 5-13: FLUX Barrier Dimensions

Manufacturer: Northern Infrastructure Products
Web Site: http:northern-ip.com/flux-moveable-concrete-barrier

5.1.4 Temporary Steel Barrier Systems

Temporary Steel Barriers (TSB) are portable barrier systems consisting of free-standing fabricated double sided steel barrier segments that are positively connected together to form a continuous barrier system. Descriptions of the various types of TSB that have been used on provincial highway projects as an alternative to temporary concrete barrier systems are provided on the following pages.

Advantages and Disadvantages:

The advantages of temporary steel barrier when compared to temporary concrete barrier are:

- Light weight and stackable;
- Larger quantities can be transported per truckload, and;
- Ideal option for bridges with weight restrictions

The disadvantages of temporary steel barrier when compared to temporary concrete barrier are:

- Systems need to be pinned at each end through pavement or concrete, and at specified intervals throughout the installation dependent on desired deflection requirements;
- More expensive to initially purchase than temporary concrete barrier; and
- Need to be placed on paved surfaces.

5.1.4.1 BarrierGuard 800

BarrierGuard 800 is a proprietary TSB that meets NCHRP Report 350 TL-3. The system consists of galvanized steel segments with a height of 800 mm, width of 540 mm at the bottom and 230 mm at the top. It is available in segment lengths of 6 m and 12 m that weigh 90 kg per metre. Adjacent segments are connected together using male and female QuickMount connectors that lock into place.

Figure 5-14: BarrierGuard 800 Temporary Steel Barrier

The system is anchored at each end and at a point approximately 6 m in from each end with steel anchor rods. The system can also be configured to minimize deflection using additional steel anchors at specified intervals dependent on thickness of asphalt or concrete.

Manufacturer: Highway Care
Web Site: https://www.highwaycareint.com/product_info/44/barrierguard800

5.1.4.2 ZoneGuard

ZoneGuard is a proprietary TSB that was developed by Hill and Smith Inc. that meets MASH TL-3. The system consists of galvanized steel segments with a height of 800 mm, width of 700 mm at the bottom, and 157 mm at the top. It is available in 15.24 m length segments weighing 1406 kg each (92 kg per meter). Adjacent segments are connected together by sliding the male end onto the female end and then sliding and bolting the engagement assembly into place at the top of the barrier.

Figure 5-15: ZoneGuard Temporary Steel Barrier Installation
Photo credit: Hill & Smith

The system is anchored using steel anchors at each end of the installation located 0.5 m and 5.1 m from the ends into asphalt or concrete. The system can also be configured to minimize deflection using additional steel anchors at specified intervals dependent on thickness of asphalt or concrete. The Minimum Deflection System additional anchors are spaced at a maximum of 10.2 m along the barriers installation length.

Manufacturer: Hill and Smith, Inc.
Web Site: http://www.hillandsmith.com/zoneguard/

5.1.4.3 Defender

The Defender is a proprietary TSB that meets MASH TL-3. The system consists of galvanized steel segments with a height of 800 mm, width of 680 mm at the bottom and 200 mm at the top. It is available in segment lengths of 3.9 m with a mass of 82 kg per metre. Adjacent segments are connected together using male and female sliding interlocking connectors and a joining pin.

Figure 5-16: Defender Barrier
Photo Courtesy of Safe Barriers

The system is anchored with 8 pins through each end unit and at 9.15m intervals on both sides of the barrier throughout the run. The system can also be configured to minimize deflection using additional steel anchors at specified intervals dependent on thickness of asphalt or concrete.

A High Containment version with reduced pin spacing is available that meets MASH TL-4. Highway Design Office shall be contacted for additional information on the use of this configuration.

Manufacturer: Safe Barriers
Web Site: https://www.safebarriers.com/download-center/

5.1.4.4 Safezone

The Safezone is a proprietary TSB that meets MASH TL-3. The system consists of galvanized steel segments with a height of 806 mm, width of 454 mm at the bottom and 295 mm at the top. Inserts that slide through the bottom of the units to facilitate placement of anchor pins increase the effective bottom width to 639mm. It is available in segment lengths of 5.801 m with a mass of 86 kg per metre. Adjacent segments are connected together using male and female QuickLink connectors that lock into place and are secured with a bolt.

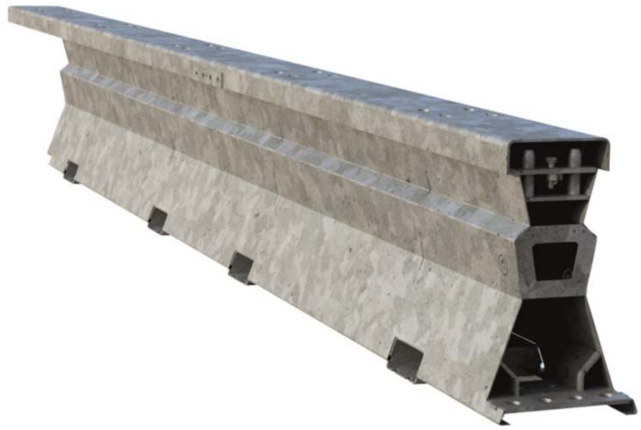


Figure 5-17: Safezone Barrier
Photo courtesy of Laura Metaal

The system is anchored at each end with 4 anchor pins. The standard installation does not use anchor pins along the run. A Limited Deflection configuration is available that utilized anchor pins along the run of barrier at a maximum spacing of 11.6m.

An alternative configuration that meets MASH TL-4 is also available. For use as a TL-4 barrier, contact Highway Design Office for guidance.

Manufacturer: Laura Metaal
Web Site: https://www.laurametaal.com/us/road-safety/temporary-barriers/safezone

5.1.4.5 HV2

The HV2 is a proprietary TSB that meets MASH TL-4. The system consists of galvanized steel segments with internal concrete ballasting with a height of 900 mm, width of 450 mm at the bottom and 200 mm at the top. It is available in segment lengths of 5.845 m with a mass of 360 kg per metre. Adjacent segments are connected together using an interlocking joiner.

Figure 5-18: HV2 Barrier
Photo Courtesy of Safe Roads

The system is unique among steel barriers in that it does not require anchoring at the ends or along the run.

Although the system has been successfully crash tested to MASH TL-4 its TL-3 parameters are specified for ministry contracts. For use as a TL-4 barrier, contact Highway Design Office for guidance.

Manufacturer: Safe Roads
Web Site: https://www.saferoads.com.au/hv2-barrier

5.1.4.6 Highway Guard

The Highway Guard is a proprietary TSB that meets MASH TL-3. The system consists of galvanized steel segments with a height of 800 mm, width of 540 mm at the bottom and 250 mm at the top. It is available in segment lengths of 6 m with a mass of 92 kg per metre. Adjacent segments are connected together using a universal T-connector.

Figure 5-19: Highway Guard Barrier
Photo Courtesy of HighwayCare

The system is anchored using six steel mechanical or chemical anchors at each end of the installation located 1.0 m, 5.0 m and 7.0 m from the ends into asphalt or concrete. Intermediate anchors placed on both sides of the barrier are placed at three interval options. The Standard Deflection System requires intermediate anchors at an interval of 58 m and has a dynamic deflection of approximately 1.95 m. The Lowest Deflection System requires intermediate anchors at an interval of 12 m, staggered across the barrier connection and has a dynamic deflection of approximately 0.7 m. The Minimum Deflection System requires intermediate anchors at an interval of 6 m staggered across the barrier connection and has a dynamic deflection of approximately 0.5 m. Each anchoring variation of the Highway Guard has symmetrical anchoring and may be used to separate opposing traffic flows.

Manufacturer: Highway Care International
Website: http://highwayguard.com

5.1.5 Temporary Type M SBGR

Temporary Type M SBGR systems have been used for temporary installations on granular roadway surfaces to provide positive protection between traffic and the work area and workers. On several projects, Temporary Type M SBGR was specified for the first stage during a culvert replacement, and subsequently removed, salvaged, and reinstalled for a subsequent stage, and then finally, removed, salvaged and reinstalled as part of the permanent roadside barrier system on the project.

The system would be specified as a new SBGR installation along with required SBEATs or SBT for stage 1, and new items were created in MTO's Contract Preparation System for removal, salvage and reinstallation for stage 2. Additional information about Type M SBGR is provided in Section 4.2.2.

5.2 Temporary Crash Cushions

Approach ends of all temporary barrier system installations should be terminated by an appropriate terminal or crash cushion standard active in MTO's Contract Preparation System. Additional information about the need for barrier terminals and performance of crash cushions for permanent installations are similar to temporary installations are provided elsewhere in this manual.

The temporary crash cushions (energy attenuators) currently specified for temporary installations on provincial highway projects are listed in Table 5-1.

Energy Attenuator	**NCHRP Report 350 or AASHTO MASH Crash Test Level**		**Temporary Installation**					
	TL-2	**TL-3**	**Reduced Exposure (RE)** (Note 2)	**Narrow (NA)**	**Wide (WI)**	**Extra Wide (EW)**	**Super Wide (SW)**	**Dual Duty (DD)**
TAU-M System (Note 1)	Yes	Yes	No	Yes	No	No	No	No
TAU-II Wide System	Yes	Yes	No	No	Yes	No	No	No
TAU-II Extra Wide System	Yes	Yes	No	No	No	Yes	No	No
ABSORB 350 System	Yes	Yes	Yes	No	No	No	No	No
ABSORB-M System (Note 1)	Yes	Yes	Yes	No	No	No	No	No
Quadguard M10 System (Note 1)	Yes	Yes	No	Yes	No	No	No	No
Quadguard Wide System	Yes	Yes	No	No	Yes	No	No	No
Quadguard Extra Wide System	Yes	Yes	No	No	No	Yes	No	No
Quadguard Super Wide System	No	Yes	No	No	No	No	Yes	No
Delta System	Yes	Yes	No	Yes	No	No	No	No
ACZ 350 System	Yes	Yes	Yes	No	No	No	No	No
Smart System (Note 1)	Yes	Yes	No	Yes	No	No	No	Yes
SLED System	Yes	Yes	Yes	No	No	No	No	No
Hercules System (Note 1)	N/A	Yes	No	Yes	No	No	No	No

Notes:
1. AASHTO MASH crash test compliant system.
2. ABSORB 350 energy attenuator system shall be used when Movable Temporary Concrete Barrier is specified.

Table 5-1: Temporary Energy Attenuators

Additional information about Tau-II, Tau-M, QuadGuard, QuadGuard M10, and Smart systems for permanent installations are provided in Section 4.4.2 which is also applicable for temporary installations of these systems. When these systems are specified for temporary installations in work zones, designers need to verify that there will be at least 150 mm of asphalt pavement over compacted granular for any of these systems to be anchored according to manufacturers recommendations. If sufficient depth of existing asphalt pavement is not available at locations where temporary energy attenuators are being installed, it will be necessary to either specify hot mix paving to provide the minimum depth of asphalt for anchoring the system or specify construction of a temporary concrete pad (or precast pad) to anchor the system. For temporary installations, the first TCB adjacent to the temporary energy attenuator also needs to be anchored to the pavement. See Figure 5-20 and applicable standards active in MTO's Contract Preparation System showing a typical temporary energy attenuator and TCB layout.

For shorter term temporary energy attenuator installations, typically three months or less, where the system isn't scheduled to be in service during winter shutdown, where existing pavement thicknesses are less than 150 mm, and where minimum one metre offsets can be provided between the travelled lane and the attenuator, reduced exposure energy attenuators should be considered. Reduced exposure attenuators consist of plastic modules that are ballasted with water, and simply sit on the pavement surface without anchors. As these systems are gating, when installed adjacent to existing barrier systems, they either need to be installed with less than 0.3 m of clearance between the system and adjacent barrier or be installed with more than 3 m clearance between the system and adjacent barrier. These systems also require a clear traversable area downstream of the system measuring at least 4 m wide by 22 m long, measured from the upstream face of the system and parallel to the system. They also require at least 16 m of tangential TCB in line with the system beyond the connection. It is also recommended that reduced exposure systems are used where the chance of high speed, high angle impacts are low and penetration behind the barrier is acceptable. If these types of collisions may occur or penetration behind the barrier is not acceptable a narrow redirective crash cushion should be used. Although anti-freezing agents may be added to the water in the modules to prevent the water from freezing, there are potential environmental concerns should a module be impacted, and the anti-freeze chemicals released into nearby ditches and waterways. Achieving a proper water and anti-freeze mixture on site may be challenging as well, particularly if the anti-freeze agent is added to water already in the module. For this reason,s it is not recommended to use reduced exposure attenuators over periods where temperatures typically fall to near or below freezing or if construction delays may result in this scenario. Additional details for installation of reduced exposure systems on the end of temporary concrete barrier installations are shown in Figure 5-21 and on the applicable standards active in MTO's Contract Preparation System.

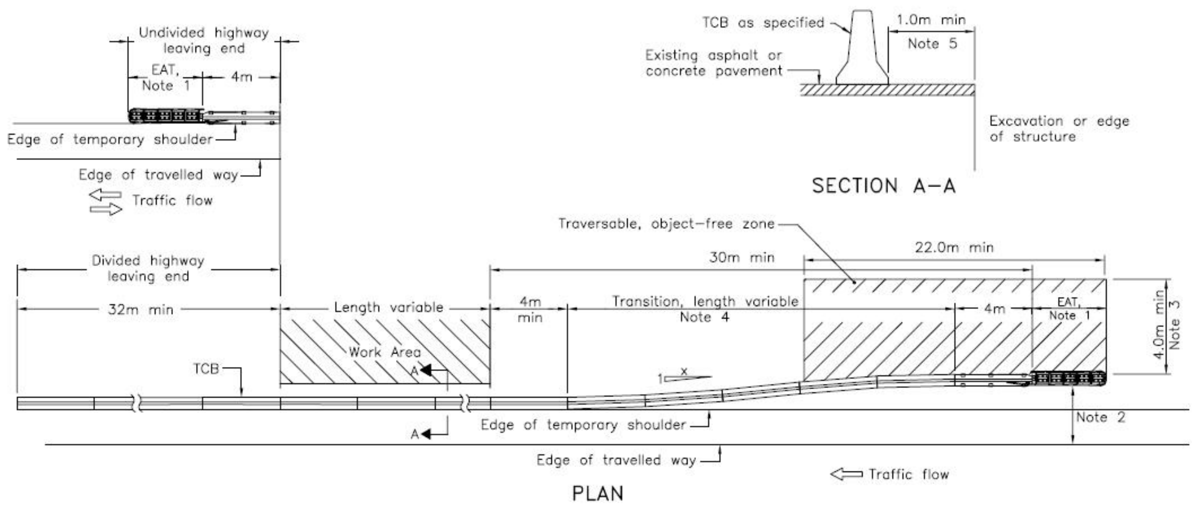


Figure 5-20: Typical TCB Layout with Temporary Energy Attenuator.
See applicable standard for Notes

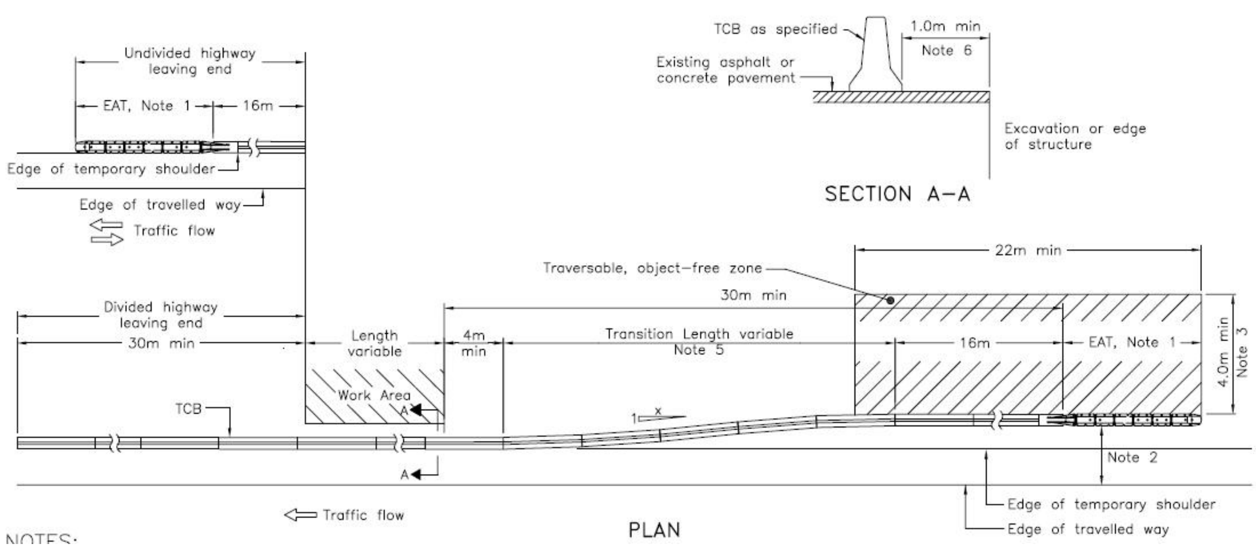


Figure 5-21: Typical TCB Layout with Temporary Reduced Exposure Energy Attenuator.
See applicable standard for Notes

5.2.1 Reduced Exposure Energy Attenuators

5.2.1.1 Absorb 350 Reduced Exposure Temporary Energy Attenuator System

The Absorb 350 System is a proprietary non-redirective, gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3.

Figure 5-22: Absorb 350 Temporary Reduced Exposure Energy Attenuator

The system consists of a nosepiece assembly followed by a series of four, eight, or nine low density polyethylene element assemblies, and a transition assembly.

There are two types of element assemblies (Type A and Type B) that are alternated when installed. Both types of elements are 1000 mm long by 800 mm tall by 610 mm wide. The first element in is not filled with water. The elements are connected together using steel pins.

The system is not anchored, but does require a paved surface.

The Absorb 350 system is also used with the Quickchange Moveable Barrier System. The ABSORB 350 System can pass through the Barrier Transition Machine during barrier shifts.

Manufacturer: Lindsay Corporation - Barrier Systems
Web Site: http://www.barriersystemsinc.com/

5.2.1.2 ABSORB-M Reduced Exposure Temporary Energy Attenuator System

The ABSORB-M System is a proprietary non-redirective, gating, crash cushion that meets the crash test acceptance requirements of MASH TL-2 and TL-3.

Figure 5-23: ABSORB-M Temporary Reduced Exposure Energy Attenuating System

The system consists of a nosepiece assembly followed by a series of two (TL-2) or three (TL-3) low density polyethylene element assemblies, and a transition assembly.

The TL-2 system is 0.45m long by 1070mm tall by 610mm wide while the TL-3 system is 0.64m long with the same width and height dimensions. The elements are connected using exterior steel rods.

The system is not anchored but does require a paved surface.

Unlike the ABSORB-350 system, The ABSORM-M cannot be used in conjunction with the Quickchange Moveable Barrier System.

Manufacturer: Lindsay Corporation - Barrier Systems
Web Site: http://www.barriersystemsinc.com/

5.2.1.3 ACZ 350 Reduced Exposure Temporary Energy Attenuator System

The ACZ 350 System is a proprietary non-redirective, gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3.

Figure 5-24: ACZ 350 Temporary Reduced Exposure Energy Attenuator

5.2.1.4 SLED Reduced Exposure Temporary Energy Attenuator System

The SLED System is a proprietary non-redirective, gating, crash cushion that meets the crash test acceptance requirements of NCHRP Report 350 TL-2 and TL-3.

Figure 5-25: SLED Temporary Reduced Exposure Energy Attenuator

The system consists of a nosepiece assembly followed by a series of four, eight, or nine low density polyethylene element assemblies, and a transition assembly.

There are two types of element assemblies (Type A and Type B) that are alternated when installed. Both types of elements are 1000 mm long by 800 mm tall by 610 mm wide. The first element in is not filled with water. The elements are connected together using steel pins.

The system is not anchored, but does require a paved surface.

Manufacturer: TraFix Devices Inc.
Web Site: https://www.traffixdevices.com/

5.3 Transitions to Temporary Concrete Barrier

Within work zones, it may be necessary to provide a positive connection between an existing permanent concrete barrier system and temporary concrete barrier installation within a work zone, or between an existing SBGR installation and a temporary concrete barrier installation within a work zone. Providing a positive connection instead of specifying a temporary energy attenuator would likely be recommended for long term work operations, including during winter shutdown periods. New crash tested standards that were implemented in 2018 for use on provincial highway projects are summarized below.

Transition from Permanent SBGR to Temporary Concrete Barrier:

The layout shown in Figure 5-26 was developed and crash tested by Midwest Roadside Safety Facility (MwRSF) according to MASH TL-3. The Type M SBGR transition between the existing SBGR installation and the TCB will need the steel posts to be installed into the granular base or gravel shoulder. The posts should not be installed through pavement. The first three units of TCB may be installed on gravel in vicinity of the connection.

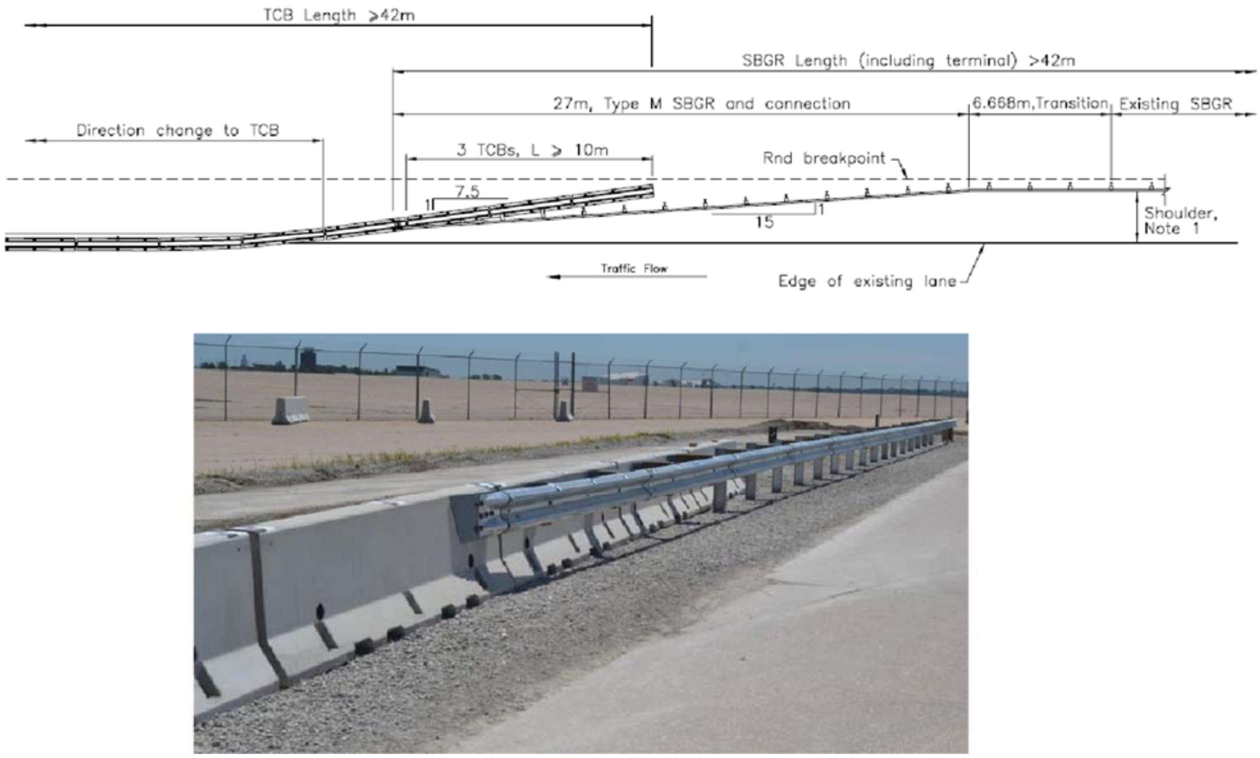


Figure 5-26: Transition from Existing SBGR to TCB
Photo courtesy of MwRSF

Transition from Permanent Concrete Barrier to Temporary Concrete Barrier:

The Concrete Barrier Temporary Transition is a proprietary redirective system that meets the crash test acceptance requirements of MASH TL-3. The system connects and transitions from permanent concrete barrier to temporary concrete barrier eliminating the need for a crash cushion. The transition includes a Steel Transition Plate that is 10.9 m long by 802 mm high and 6.35 mm thick. The Steel Transition Plate is angled at 3.1 degrees between the existing permanent concrete barrier and three pinned 4 m long modified Type X TCB units. The barrier following the three pinned Type X temporary concrete barrier can either continue as Type X or be transitioned to another type of temporary concrete barrier.

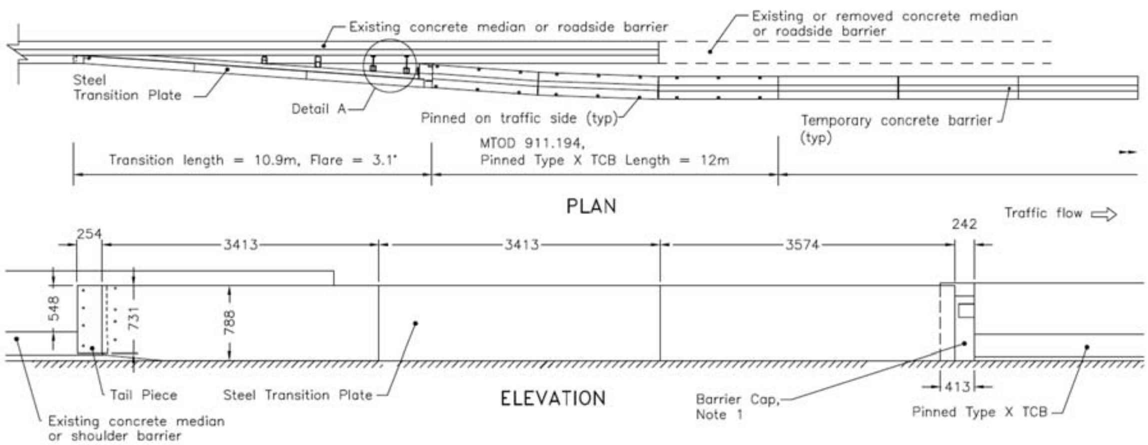


Figure 5-27: Transition from Permanent Concrete Barrier to Temporary Concrete Barrier
Photo courtesy of Powell Construction and TTI.

Manufacturer: Northern Infrastructure Products Inc.
Web Site: http://www.northern-ip.com

5.4 Temporary Work Zone Signs

5.4.1 Skid-Mounted Temporary Sign Supports

The skid-mounted sign support system is a non-proprietary breakaway sign support design that meets the crash test acceptance requirements of MASH TL-3. It was tested for the Texas Department of Transportation by the Texas Transportation Institution in 2014.

The system consists of a sign board, fastened to either a two or three post support system using wooden posts (although a 5-post support system was crash tested as shown in Figure 5-28). The supports are fastened to a wooden skid base which is placed on the surface of the roadside in a construction zone. The wooden skid base is weighed down using 18 kg sandbags. Two 51 mm holes are drilled at the bottom of the posts to facilitate predictable fracturing.

Sign support dimensions, post spacing and number of sandbags are dependent on the sign board area. For two-post sign support system, sign sizes ranging from 90-180 cm wide x 105-180 cm high to a maximum sign area of 3.24 m² can be used. For three-post sign support system, sign sizes ranging from 210-240 cm wide x 180-210 cm high to a maximum sign area of 5.04 m² may be installed.

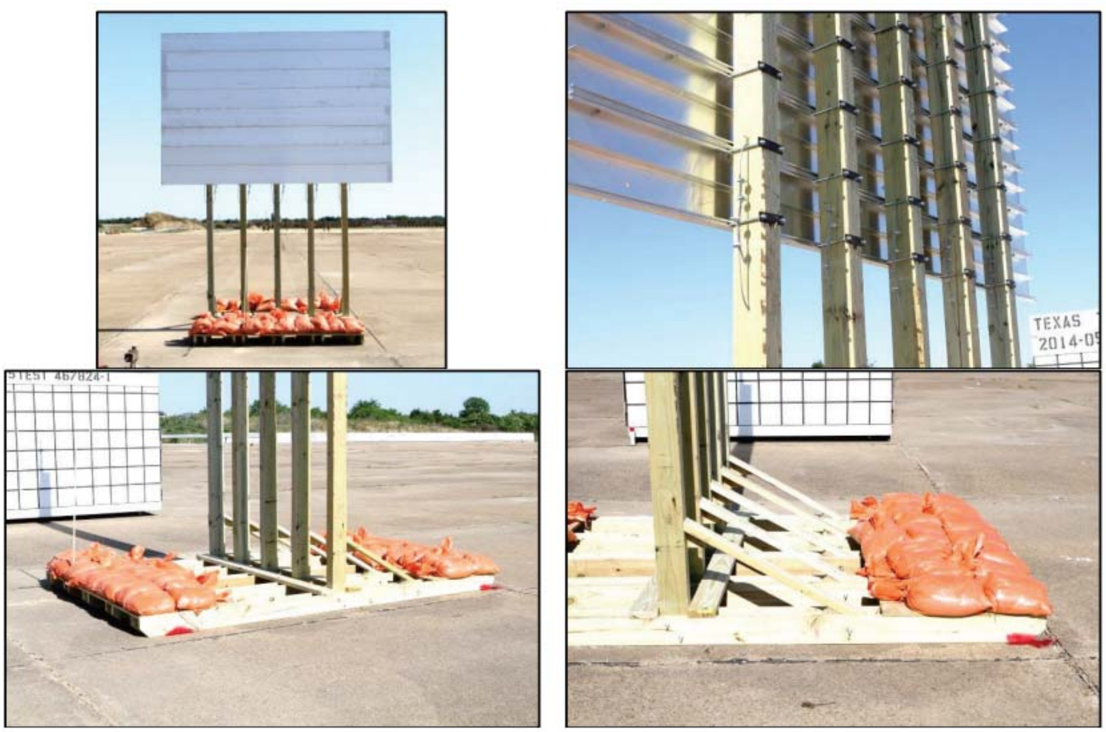


Figure 5-28, Skid-Mounted Temporary Sign Support

In head on impacts, the wooden sign supports fracture at bumper height and below the sign board. The skid base also is displaced slightly in the direction of travel of the impacting vehicle.

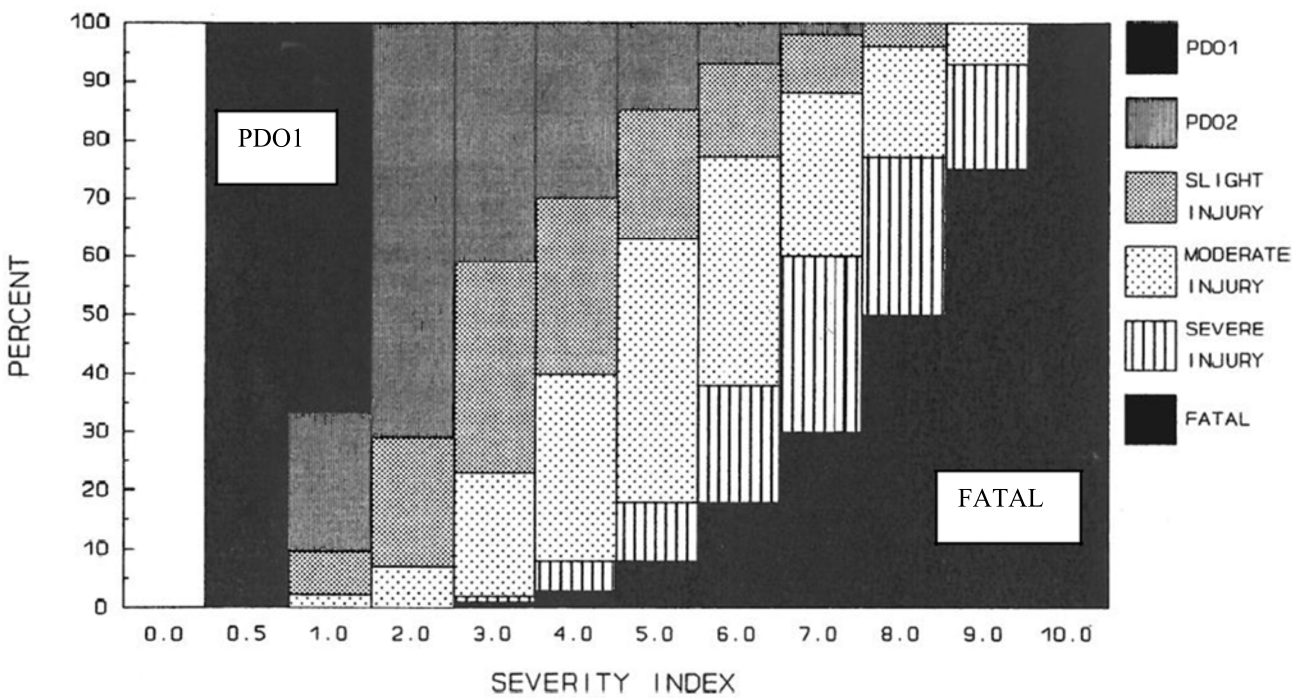
This sign support should only be used on terrain with a maximum transverse slope of 10H:1V and should not be used in locations with a potential of impacts other than by a vehicle approaching the broad side of the sign support.

Appendix A: MTO Severity Index Tables

1. Severity Indices

The MTO Severity Index Tables are based primarily on the Suggested Severity Indices Tables in Appendix A of the AASHTO Roadside Design Guide (1996) and NCHRP Synthesis 202 Severity Indices for Roadside Features (1994). The MTO Severity Index Tables are used during preparation of Guide Rail Evaluation Reports on highway rehabilitation and reconstruction projects to justify replacement of barriers and for evaluation of alternative roadside safety treatments using MTO's Roadside Evaluation Manual and MTO's Roadside.xlsx program.

Severity Indices (SI) are based on a zero to ten scale. An SI of zero represents a roadside feature that will likely not result in any damage or injury when impacted or traversed by an errant vehicle. An SI of 10 represents a roadside feature that will likely result in a fatal crash when impacted or traversed by an errant vehicle. Table A-1 shows the distribution of collision classifications estimated within each SI. For example, a roadside feature with an SI of 4.0 when impacted or traversed by an errant vehicle has an estimated probability of 30% of resulting in property damage only, a 67% probability of being an injury crash, and 3% probability of being a fatal crash.



Collision Type Distribution vs Severity Index
(AASHTO Roadside Design Guide, Figure A.8, 1996)
Table A-1

SI values have been developed for many roadside features for a range of design speeds from 50km/h to 120km/h. Roadside features listed in the MTO Severity Index tables include various foreslope and backslope configurations, drainage ditches, and various objects such as trees, poles, piers, barriers, terminal systems, and culvert treatments.

2. Surface Condition:

For foreslopes, backslopes, and intersecting slopes, different surface conditions for selecting the appropriate SI for evaluations are described in Table A-2. Existing slopes that are relatively uniform, firm, and well drained should be assumed to have Type A Surface Conditions. This would also apply to new slopes constructed in accordance with OPSS 206.

SURFACE CONDITION	DESCRIPTION
A	Smooth and firm all seasons
B	Smooth but subject to deep rutting by errant vehicles half of the year
C	Shallow gullies (100 to 200 mm deep), scattered small boulders (under 225-mm projections), scattered small trees (diameters 75 to 100 mm) , or structurally substantial woody brush. Features spaced so that nearly all encroaching vehicles will encounter them.
D	Medium gullies (approximately 250 mm deep), boulders or riprap (projecting approximately 300 mm), or medium trees (diameters 175 to 225 mm). Features spaced so that they will be encountered by all encroaching vehicles. It is assumed that density of features will preclude deep penetration of roadside. If this assumption is not valid, Sis for high, steep slopes may be considerably higher than values shown.
E	Deep gullies (over 0.5 m deep), large boulders or heavy riprap (over 450-mm projecting), large trees (diameters over 350 mm). Features spaced so that they will be encountered by all encroaching vehicles. It is assumed that density of features will preclude deep penetration of roadside. If this assumption is not valid, SIs for high, steep slopes may be considerably higher than values shown

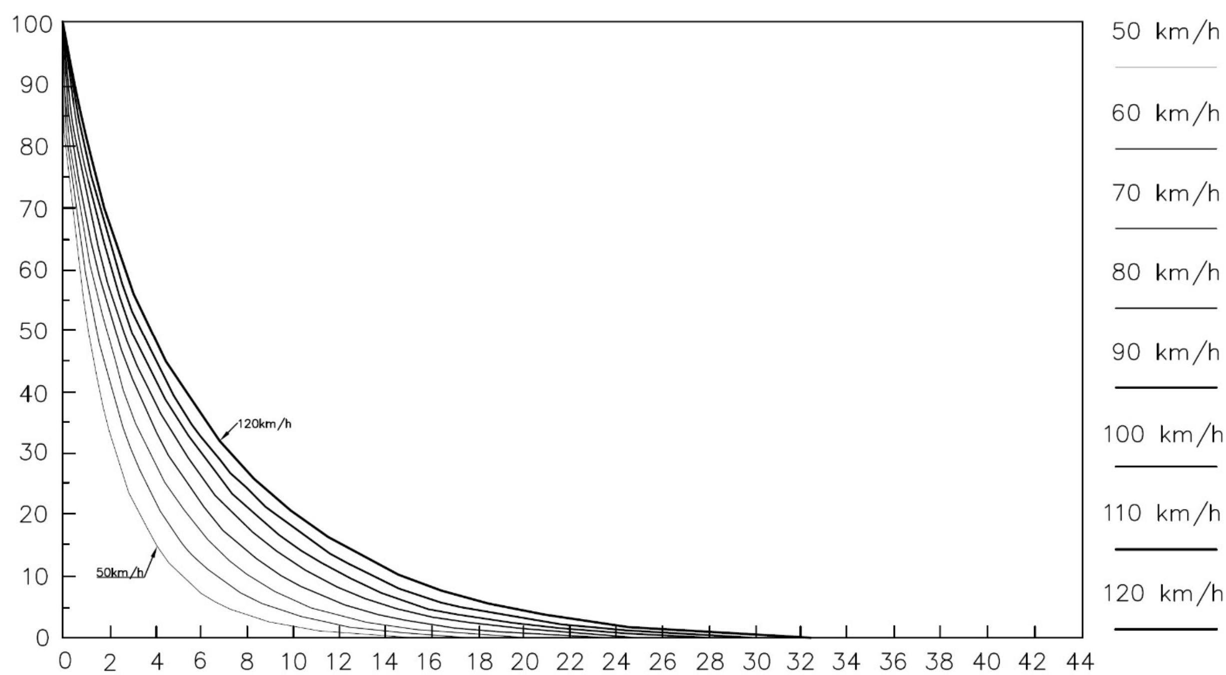
Surface Condition for Selection of Severity Index for Foreslopes and Backslopes
(AASHTO Roadside Design Guide, Table A.13.1, Page A-47, 1996)
Table A-2

3. Adjusting Offset Distances for Slopes (For Roadside.xlsx):

Roadside foreslopes and backslopes affect encroaching vehicles in two basic ways. The steepness and roughness of a slope affects the severity of the encroachment, and the steepness and orientation of the slope affects the lateral extent of the encroachment beyond the travelled way.

A critical foreslope (steeper than 3H:1V) will have a higher SI than a recoverable foreslope (e.g. 4H:1 or flatter), as the probability of an errant vehicle overturning on a critical slope is significantly higher than on a recoverable slope. The SIs for critical, non-recoverable, and recoverable foreslopes also increases as the height of the embankment increases.

Estimated lateral extent of encroachment probabilities for errant vehicles starting at 0m (edge of travelled way which 100% of errant vehicles encroach beyond) out to 45m in 0.25m increments for a range of design speeds from 50km/h to 120km/h are available in Tables A.1.1 through A.1.8 in Appendix A of the AASHTO Roadside Design Guide (1996). The referenced tables are also summarized in the graph presented in Figure A-1 below.



Lateral Extent of Encroachment vs Probability
(AASHTO Roadside Design Guide, Figure A.1, Page A-11, 1996)
Figure A-1

The steepness and orientation of a foreslope or backslope adjacent to a high-speed highway affects the lateral extent of the encroachment beyond the travelled way. If the roadside is sloping upward (positive), the probability that the errant vehicle will encroach a specified distance from the travelled way is reduced due to the beneficial effect of the upward slope on braking and steering. Conversely, if the roadside is sloping downward (negative), the probability that the errant vehicle will encroach beyond a specified distance is increased due to the negative effect of the downward slope. For evaluation of objects located on or beyond slopes, or for evaluation of areas of concern such as foreslopes, backslopes, or roadside ditches, it is necessary to adjust the horizontal lateral offsets measured from plans or in the field. For this reason, adjusted lateral offsets should be used for evaluation of objects or areas of concern using Roadside.xlsx.

Adjusted lateral offsets should be calculated by multiplying the distance or width on a given slope by a slope equivalency factor as follows:

$$E_S = (f + s) / f = 1 + s / f$$

Where: E_s = slope equivalency factor
f = braking and cornering coefficient of friction = 0.4
s = slope of the foreslope or backslope (rise divided by run)

Where slopes have differing steepness, the equivalent width of each portion should be calculated and summed to determine the total adjusted offset.

To illustrate how the steepness and orientation of slopes, and the applicable slope equivalency factor affects the lateral extent of the encroachment beyond the travelled way, see Example 1.

Example 1:

Figure A-2 shows a large tree offset 10m from the travelled way, and the roadside is flat (slopes of 10H:1V or flatter). For a design speed of 120 km/h, in accordance with Table A.1.8 in the AASHTO Roadside Design Guide (1996), the probability of errant vehicles encroaching laterally by more than 10.0m from the travelled way is 20%.

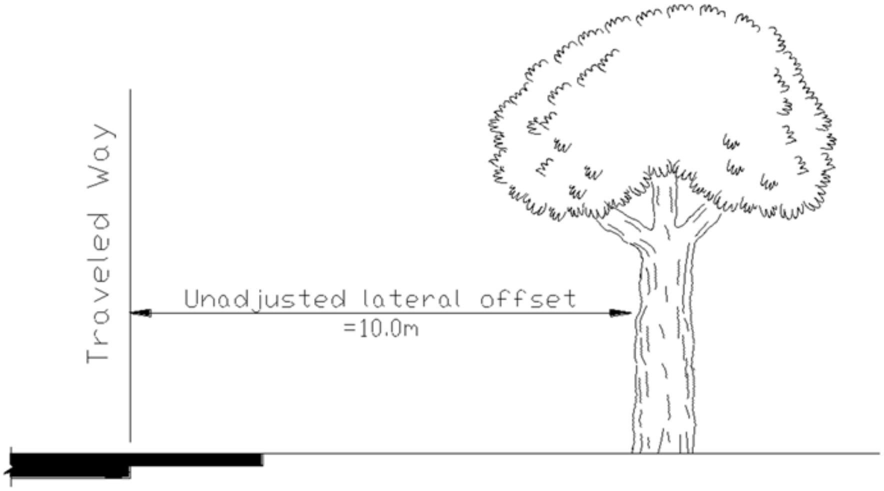


Figure A-2

Figure A-3 also shows a large tree offset 10m from the travelled way, however, the tree is located 1.5m beyond the toe of a 4H:1V (negative) foreslope. To account for the downward slope, the 5.0m wide 4H:1V slope is multiplied by E_S, resulting in an adjusted width of 1.87m for the slope ($E_S = 1 + (-0.25 / 0.4) = 0.375$). Therefore, the total adjusted lateral offset to the tree from the travelled way is 6.87m (3.0 + 0.5 + 1.87 + 1.5). For a design speed of 120 km/h, in accordance with Table A.1.8 in the AASHTO Roadside Design Guide (1996), the probability of errant vehicles encroaching laterally by more than 7.0m from the travelled way is 35%.

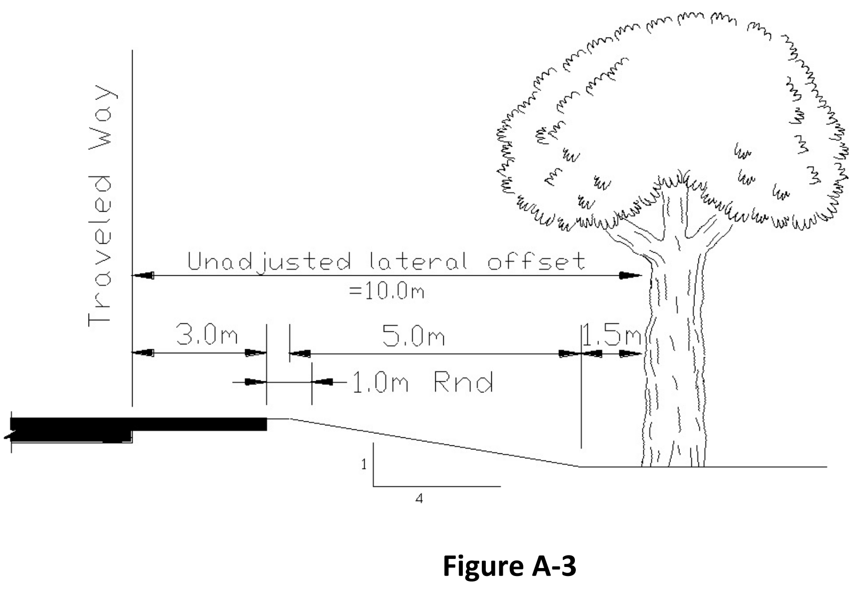


Figure A-3

Conversely, as shown in Figure A-4, a large tree is still offset 10m from the travelled way, but located at the top of a 6.6m wide 3H:1V (positive) backslope. To account for the upward slope, the 6.6m wide 3H:1V (positive) slope is multiplied by E_S, resulting in an adjusted width of 12.04m for the slope (E_s = 1 + (0.33 / 0.4) = 1.825). Therefore, the total adjusted lateral offset to the tree from the travelled way is 15.45m (3.0 + 0.4 + 12.04). For a design speed of 120 km/h, in accordance with Table A.1.8 in the AASHTO Roadside Design Guide (1996), the probability of errant vehicles encroaching laterally by more than 15.5m from the travelled way is 9 %.

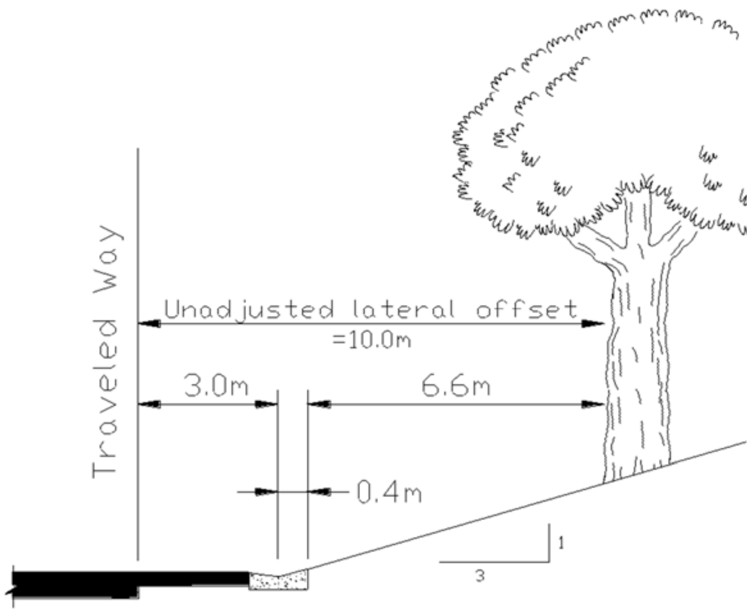


Figure A-4

Severity Indices:

Foreslopes: 10:1V and 8H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope ∞ :1 (Flat)	0.0	A	F	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8
		B	F	0.3	0.4	0.4	0.5	0.6	0.8	1.0	1.1
		C	F	0.4	0.6	0.8	1.0	1.1	1.3	1.5	1.8
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Foreslope 10H:1V	0.15	A	F	0.2	0.3	0.5	0.6	0.7	0.9	1.1	1.2
		B	F	0.4	0.5	0.7	0.8	0.9	1.1	1.3	1.6
		C	F	0.7	0.9	1.1	1.3	1.4	1.6	1.9	2.2
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 0.3	A	F	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.3
		B	F	0.6	0.7	0.9	1.0	1.2	1.4	1.6	1.9
		C	F	0.9	1.1	1.3	1.5	1.7	1.9	2.2	2.5
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Foreslope 8H:1V	0.15	A	F	0.3	0.4	0.6	0.7	0.8	1.0	1.2	1.3
		B	F	0.5	0.6	0.8	0.9	1.0	1.2	1.4	1.7
		C	F	0.8	1.0	1.2	1.4	1.5	1.7	2.0	2.3
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 0.3	A	F	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.9
		B	F	0.6	0.8	1.0	1.2	1.4	1.6	1.9	2.2
		C	F	0.9	1.2	1.4	1.7	1.9	2.1	2.5	2.9
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 6H:1V and 4H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index Design Speed – km/h							
Slope (H:V)	Height	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 6H:1V	0.15	A	F	0.5	0.8	1.0	1.3	1.5	1.7	1.9	2.0
		B	F	0.7	1.0	1.2	1.5	1.7	1.9	2.1	2.2
		C	F	1.1	1.4	1.7	2.0	2.2	2.4	2.6	2.9
		D	F	2.9	3.4	3.9	4.4	4.9	5.5	5.9	6.3
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	6.9
	≥ 0.3	A	F	0.5	0.8	1.0	1.3	1.6	1.9	2.1	2.2
		B	F	0.7	1.0	1.2	1.5	1.8	2.1	2.3	2.6
		C	F	1.1	1.4	1.7	2.0	2.3	2.6	2.9	3.2
		D	F	3.0	3.8	4.0	4.5	5.0	5.6	6.0	6.4
		E	F	3.4	3.8	4.2	4.7	5.3	5.9	6.5	7.0
Foreslope 4H:1V	0.15	A	F	0.5	0.7	0.9	1.1	1.3	1.5	1.7	2.0
		B	F	0.7	0.9	1.1	1.3	1.5	1.7	2.0	2.3
		C	F	1.0	1.3	1.5	1.8	2.0	2.2	2.6	3.0
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.0	6.4
		E	F	3.4	3.8	4.2	4.7	5.3	5.9	6.5	7.0
	0.3	A	F	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.5
		B	F	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.9
		C	F	1.7	2.0	2.2	2.5	2.7	2.9	3.2	3.5
		D	F	3.2	3.6	4.0	4.5	5.0	5.6	6.0	6.4
		E	F	3.5	3.9	4.3	4.8	5.4	6.0	6.6	7.1
	≥ 2	A	F	1.3	1.6	1.8	2.1	2.3	2.5	2.7	2.8
		B	F	1.5	1.8	2.0	2.3	2.5	2.7	2.9	3.2
		C	F	1.9	2.2	2.5	2.8	3.0	3.2	3.5	3.7
		D	F	3.2	3.6	4.0	4.5	5.0	5.6	6.0	6.4
		E	F	3.5	3.9	4.3	4.8	5.4	6.0	6.6	7.1

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 3H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height m	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 3H:1V	0.15	A	F								
		B	F								
		C	F	1.2	1.5	1.7	2.0	2.2	2.5	2.9	3.3
		D	F	3.2	3.6	4.0	4.5	5.0	5.6	6.0	6.4
		E	F	3.5	3.9	4.3	4.8	5.4	6.0	6.6	7.1
	0.3	A	F	1.6	1.8	2.0	2.2	2.4	2.6	2.8	2.9
		B	F	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.3
		C	F	2.0	2.3	2.5	2.9	3.1	3.4	3.6	3.9
		D	F	3.3	3.7	4.1	4.6	5.1	5.7	6.1	6.5
		E	F	3.6	4.0	4.4	4.9	5.5	6.1	6.7	7.2
	0.6	A	F	1.7	1.9	2.1	2.3	2.5	2.8	2.9	3.0
		B	F	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.4
		C	F	2.2	2.5	2.7	3.0	3.2	3.5	3.7	4.0
		D	F	3.3	3.7	4.1	4.6	5.1	5.7	6.1	6.5
		E	F	3.6	4.0	4.4	4.9	5.5	6.1	6.7	7.2
	1.2	A	F	1.8	2.0	2.2	2.5	2.7	3.0	3.1	3.1
		B	F	2.0	2.2	2.4	2.7	2.9	3.1	3.3	3.6
		C	F	2.3	2.6	2.9	3.2	3.4	3.6	3.9	4.2
		D	F	3.3	3.7	4.1	4.6	5.1	5.7	6.1	6.5
		E	F	3.6	4.0	4.4	4.9	5.5	6.1	6.7	7.2
	2	A	F	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.6
		B	F	2.2	2.5	2.7	3.0	3.2	3.5	3.7	4.0
		C	F	2.6	2.9	3.2	3.5	3.7	4.0	4.3	4.6
		D	F	3.4	3.8	4.2	4.7	5.2	5.8	6.2	6.6
		E	F	3.7	4.1	4.5	5.0	5.6	6.2	6.8	7.3

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 3H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height m	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 3H:1V (cont.)	4	A	F	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.6
		B	F	2.2	2.5	2.8	3.1	3.3	3.6	3.9	4.2
		C	F	2.5	2.8	3.2	3.6	3.8	4.1	4.5	4.9
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	6.9	7.4
	6	A	F	2.1	2.6	2.8	3.2	3.4	3.7	3.9	4.0
		B	F	2.2	2.7	2.9	3.3	3.5	3.8	4.1	4.3
		C	F	2.5	2.8	3.2	3.6	3.8	4.2	4.6	5.0
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	6.9	7.4
	8	A	F	2.2	2.6	3.0	3.4	3.6	3.9	4.1	4.2
		B	F	2.3	2.7	3.1	3.5	3.7	4.0	4.2	4.3
		C	F	2.5	2.8	3.2	3.6	3.9	4.2	4.6	5.0
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	6.9	7.4
	≥10	A	F	2.3	2.7	3.1	3.5	3.7	4.0	4.2	4.3
		B	F	2.4	3.0	3.4	3.8	4.0	4.3	4.4	4.5
		C	F	2.5	3.3	3.7	4.1	4.3	4.6	4.7	5.1
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.3	5.1	5.7	6.3	6.9	7.4

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 2H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height m	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 2H:1V	0.15	A	F	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.6
		B	F	2.2	2.5	2.8	3.1	3.3	3.6	3.9	4.2
		C	F	2.5	2.8	3.2	3.6	3.8	4.1	4.5	4.9
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	6.9	7.4
	0.3	A	F	2.1	2.6	2.8	3.2	3.4	3.7	3.9	4.0
		B	F	2.2	2.7	2.9	3.3	3.5	3.8	4.1	4.3
		C	F	2.5	2.8	3.2	3.6	3.8	4.2	4.6	5.0
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	6.9	7.4
	0.6	A	F	2.2	2.6	3.0	3.4	3.6	3.9	4.1	4.2
		B	F	2.3	2.7	3.1	3.5	3.7	4.0	4.2	4.3
		C	F	2.5	2.8	3.2	3.6	3.9	4.2	4.6	5.0
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	6.9	7.4
	1.2	A	F	2.3	2.7	3.1	3.5	3.7	4.0	4.2	4.3
		B	F	2.4	3.0	3.4	3.8	4.0	4.3	4.4	4.5
		C	F	2.5	3.3	3.7	4.1	4.3	4.6	4.7	5.1
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.3	5.1	5.7	6.3	6.9	7.4
	2	A	F	2.9	3.2	3.5	3.8	4.0	4.3	4.5	4.8
		B	F	2.3	2.9	3.4	4.0	4.2	4.5	4.8	5.1
		C	F	2.6	3.2	3.9	4.5	4.7	5.0	5.4	5.8
		D	F	3.5	3.9	4.3	4.8	5.3	5.9	6.3	6.7
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	6.9	7.4

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 2H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 2H:1V (cont.)	4	A	F	3.1	3.4	3.8	4.2	4.4	4.6	4.8	5.1
		B	F	2.5	3.1	3.8	4.4	4.6	4.8	5.1	5.4
		C	F	2.8	3.5	4.2	4.9	5.1	5.3	5.7	6.1
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	6	A	F	3.3	3.6	3.9	4.3	4.5	4.7	4.9	5.2
		B	F	3.2	3.6	4.1	4.5	4.7	4.9	5.2	5.5
		C	F	2.9	4.0	4.5	4.9	5.2	5.4	6.1	6.2
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	8	A	F	3.6	3.9	4.1	4.4	4.6	4.8	5.0	5.3
		B	F	3.8	4.1	4.3	4.6	4.8	5.0	5.3	5.6
		C	F	4.1	4.4	4.7	5.0	5.2	5.4	5.8	6.2
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	10	A	F	4.1	4.3	4.5	4.7	4.9	5.2	5.4	5.5
		B	F	4.2	4.4	4.6	4.8	5.0	5.3	5.5	5.8
		C	F	4.4	4.7	4.9	5.2	5.4	5.7	6.0	6.3
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	14	A	F	4.5	4.7	4.9	5.1	5.3	5.5	5.7	6.0
		B	F	4.6	4.8	5.0	5.2	5.4	5.6	5.9	6.2
		C	F	4.7	5.0	5.2	5.5	5.7	5.9	6.3	6.7
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 2H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 2H:1V (cont.)	18	A	F	4.8	5.0	5.2	5.4	5.6	5.8	6.0	6.3
		B	F	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.4
		C	F	4.9	5.2	5.4	5.7	5.9	6.1	6.4	6.7
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	22	A	F	4.9	5.1	5.3	5.5	5.7	5.9	6.1	6.4
		B	F	5.0	5.2	5.4	5.6	5.8	6.0	6.2	6.5
		C	F	5.1	5.3	5.5	5.7	5.9	6.2	6.5	6.8
		D	F	3.8	4.1	4.5	4.9	5.4	6.	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	26	A	F	4.8	5.1	5.3	5.6	5.8	6.1	6.3	6.4
		B	F	4.9	5.2	5.4	5.7	5.9	6.2	6.4	65
		C	F	5.0	5.3	5.5	5.8	6.0	6.3	6.6	6.9
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	30	A	F	4.8	5.1	5.32	5.6	5.9	6.2	6.4	6.5
		B	F	4.9	5.2	5.4	5.7	6.0	6.3	6.5	6.6
		C	F	5.0	5.3	5.5	5.8	6.1	6.4	6.6	6.9
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.4	6.8
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5
	≥34	A	F	4.8	5.1	5.3	5.6	5.9	6.2	6.4	6.7
		B	F	4.9	5.3	5.4	5.7	6.0	6.3	6.5	6.8
		C	F	5.0	5.3	5.5	5.8	6.1	6.4	6.6	6.9
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.6	7.3
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.0	7.5

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

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Foreslopes: 1.5H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 1.5H:1V (cont.)	0.15	A	F	0.9	1.3	1.7	2.2	2.4	2.7	3.0	3.3
		B		1.1	1.5	1.9	2.4	2.6	2.9	3.3	3.7
		C	F	1.4	1.9	2.4	2.9	3.1	3.5	3.9	4.3
		D		3.3	3.8	4.3	4.8	5.3	5.9	6.3	6.7
		E		3.7	4.1	4.5	5.0	5.6	6.2	6.8	7.3
	0.3	A		2.4	2.6	2.8	3.0	3.2	3.5	3.7	4.0
		B		2.6	2.8	3.0	3.2	3.4	3.7	4.0	4.3
		C	F	2.9	3.2	3.4	3.7	3.9	4.2	4.6	5.0
		D	F	3.3	3.8	4.3	4.8	5.3	5.9	6.4	6.9
		E	F	3.7	4.1	4.5	5.0	5.6	6.2	6.9	7.6
	2	A	F	3.3	3.6	3.9	4.2	4.5	4.8	5.0	5.3
		B	F	3.2	3.5	3.7	4.0	4.4	4.8	5.2	5.6
		C	F	3.6	3.9	4.2	4.5	4.9	5.3	5.8	6.3
		D	F	3.4	3.9	4.4	4.9	5.4	6.0	6.5	7.0
		E	F	3.7	4.1	4.5	5.0	5.6	6.2	6.9	7.6
	4	A	F	3.8	4.1	4.4	4.7	4.9	5.2	5.4	5.7
		B	F	3.8	4.1	4.5	4.9	5.4	5.9	6.2	6.5
		C	F	4.8	5.0	5.2	5.4	5.8	6.3	6.8	7.3
		D	F	3.8	4.1	4.5	4.9	5.4	6.0	6.5	7.0
		E	F	3.8	4.2	4.6	5.1	5.7	6.3	7.0	7.7
	6	A	F	4.1	4.4	4.7	5.0	5.2	5.5	5.7	6.0
		B	F	4.7	4.4	4.7	5.5	5.9	6.3	6.6	7.0
		C	F	5.3	5.4	5.7	5.9	6.2	6.7	7.2	7.6
		D	F	3.9	4.2	4.6	5.0	5.5	6.0	6.6	7.2
		E	F	3.9	4.3	4.7	5.1	5.8	6.4	7.1	7.8

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 1.5H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 1.5H:1V (cont.)	8	A	F	4.3	4.6	4.9	5.2	5.4	5.7	5.9	6.2
		B	F	5.5	5.6	5.8	5.9	6.3	6.6	7.0	7.4
		C	F	5.7	5.9	6.1	6.3	6.6	7.0	7.5	8.0
		D	F	3.9	4.2	4.6	5.0	5.5	6.0	6.6	7.3
		E	F	3.9	4.3	4.7	5.2	5.8	6.4	7.1	7.8
	10	A	F	4.9	5.2	5.4	5.7	6.0	6.3	6.6	6.9
		B	F	6.4	6.5	6.7	6.8	7.2	7.6	7.8	8.1
		C	F	6.8	6.9	7.1	7.2	7.6	8.0	8.2	8.5
		D	F	4.0	4.3	4.7	5.1	5.6	6.1	6.7	7.4
		E	F	4.0	4.4	4.8	5.3	5.9	6.5	7.2	7.9
	14	A	F	5.4	5.7	5.9	6.2	6.6	6.9	7.2	7.5
		B	F	7.1	7.2	7.4	7.5	7.9	8.2	8.5	8.8
		C	F	7.5	7.6	7.8	7.9	8.2	8.5	8.8	9.1
		D	F	4.0	4.3	4.7	5.1	5.6	6.1	6.7	7.4
		E	F	4.0	4.4	4.8	5.3	5.9	6.5	7.2	7.9
	18	A	F	5.8	6.1	6.4	6.7	7.1	7.4	7.7	8.0
		B	F	7.6	7.7	7.9	8.0	8.4	8.7	9.0	9.3
		C	F	7.9	8.0	802	8.3	8.6	8.9	9.2	9.5
		D	F	4.0	4.3	4.7	5.1	5.6	6.1	6.7	7.4
		E	F	4.0	4.4	4.8	5.3	5.9	6.5	7.2	7.9
	22	A	F	6.2	6.5	6.8	7.1	7.4	7.7	8.0	8.3
		B	F	7.7	7.9	8.1	8.3	8.6	8.9	9.1	9.2
		C	F	8.0	8.2	8.4	8.6	8.8	9.1	9.3	9.4
		D	F	4.0	4.3	4.7	5.1	5.6	6.1	6.7	7.4
		E	F	4.2	4.5	4.9	5.3	5.9	6.5	7.2	7.9

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: 1.5H:1V

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Foreslope 1.5H:1V (cont.)	26	A	F	6.3	6.6	6.9	7.2	7.5	7.8	8.1	8.4
		B	F	7.9	8.1	8.3	8.5	8.8	9.1	9.3	9.6
		C	F	8.0	8.3	8.5	8.8	9.0	9.2	9.4	9.7
		D	F	4.1	4.4	4.8	5.2	5.6	6.1	6.7	7.4
		E	F	4.2	4.5	4.9	5.3	5.9	6.5	7.2	7.9
	30	A	F	6.6	6.9	7.1	7.4	7.7	8.0	8.3	8.6
		B	F	7.8	8.1	8.3	8.6	8.8	9.1	9.4	9.7
		C	F	8.0	8.3	8.5	8.8	9.0	9.2	9.4	9.7
		D	F	4.1	4.4	4.8	5.2	5.54	6.1	6.7	7.4
		E	F	4.2	4.5	4.9	5.3	5.9	6.5	7.2	7.9
	34	A	F	6.8	7.1	7.3	7.6	7.8	8.1	8.4	8.7
		B	F	7.9	8.2	8.4	8.7	8.9	9.2	9.4	9.7
		C	F	8.1	8.4	8.6	8.9	9.0	9.21	9.4	9.7
		D	F	4.1	4.4	4.8	5.2	5.6	6.1	6.7	7.4
		E	F	4.2	4.5	4.9	5.3	5.9	6.5	7.2	7.9
	≥ 38	A	F	6.9	7.2	7.4	7.7	7.9	8.2	8.5	8.8
		B	F	8.0	8.3	8.5	8.8	9.0	9.3	9.5	9.8
		C	F	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.8
		D	F	4.1	4.4	4.8	5.2	5.6	6.1	9.7	7.4
		E	F	4.2	4.5	4.9	5.3	5.9	6.5	7.2	7.9

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: Vertical with and without water present:

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Water Depth (m)		50	60	70	80	90	100	110	120
Foreslope Vertical (Drop-Off)	0	0	F	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8
		1	F	2.6	2.7	2.9	3.0	3.2	3.4	3.6	3.7
		2	F	4.4	4.7	4.9	5.2	5.4	5.7	5.9	6.2
		4	F	6.2	6.4	6.6	6.8	7.0	7.2	7.4	7.7
		≥6	F	7.9	8.1	8.3	8.5	8.7	8.8	9.0	9.1
	0.3	0	F	2.6	2.9	3.1	3.4	3.6	3.9	4.1	4.4
		1	F	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.7
		2	F	4.6	4.9	5.2	5.5	5.9	6.2	6.6	7.0
		4	F	6.3	6.6	6.9	7.2	7.4	7.7	7.9	8.2
		≥6	F	8.2	8.3	8.5	8.6	8.8	9.0	9.2	9.3
	2	0	F	3.8	4.1	4.3	4.6	4.8	5.1	5.3	5.6
		1	F	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.7
		2	F	6.7	6.8	7.0	7.1	7.3	7.5	7.7	7.8
		4	F	7.6	7.7	7.9	8.0	8.2	8.4	8.6	8.7
		≥6	F	8.4	8.5	8.7	8.8	9.0	9.2	9.4	9.5
	4	0	F	5.7	5.8	5.8	5.9	6.1	6.3	6.5	6.6
		1	F	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.0
		2	F	7.4	7.5	7.7	7.8	8.0	8.2	8.4	8.5
		4	F	8.0	8.1	8.3	8.4	8.6	8.8	9.0	9.1
		≥6	F	8.6	8.7	8.9	9.0	9.2	9.4	9.6	9.7
	6	0	F	6.6	6.7	6.8	6.9	7.0	7.2	7.4	7.5
		1	F	6.8	6.9	7.1	7.3	7.4	7.6	7.8	7.9
		2	F	7.8	7.9	8.1	8.2	8.4	8.6	8.8	8.9
		4	F	8.2	8.3	8/.5	8.7	8.9	9.1	9.3	9.4
		≥6	F	8.7	8.8	9.0	9.1	9.3	9.5	9.7	9.8

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Foreslopes: Vertical with and without water present (continued):

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Water Depth (m)		50	60	70	80	90	100	110	120
Foreslope Vertical (Drop-Off)	8	0	F	7.4	7.5	7.7	7.8	7.9	8.0	8.2	8.3
		1	F	7.8	7.9	8.1	8.2	8.3	8.4	8.6	8.7
		2	F	8.1	8.2	8.4	8.5	8.7	8.9	9.1	9.2
		4	F	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.6
		≥6	F	8.8	8.9	9.1	9.2	9.4	9.6	9.8	9.9
	10	0	F	8.6	8.8	9.0	9.2	9.2	9.2	9.3	9.3
		1	F	8.7	8.9	9.1	9.3	9.4	9.4	9.6	9.7
		2	F	9.2	9.3	9.3	9.4	9.5	9.6	9.8	9.9
		4	F	9.5	9.6	9.6	9.7	9.8	9.8	9.9	9.9
		≥6	F	9.7	9.8	9.8	9.9	10.0	10.0	10.0	10.0
	14	0	F	9.5	9.6	9.6	9.7	9.8	9.8	9.8	9.8
		1	F	9.6	9.7	9.7	9.8	9.8	9.8	9.9	9.9
		2	F	9.6	9.7	9.7	9.8	9.9	9.9	10.0	10.0
		4	F	9.8	9.9	9.9	10.0	10.0	10.0	10.0	10.0
		≥6	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	18	0	F	9.9	9.9	9.9	9.9	9.9	9.9	10.0	10.0
		1	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		2	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		4	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		≥6	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
	≥ 22	0	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		1	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		2	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		4	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		≥6	F	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Backslopes: Located beyond 10H:1V foreslopes (positive or negative) and beyond parallel flat bottom roadside ditches with ditch bottom 2.5 m wide or greater.

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Backslope 10H:1V	0.15	A	F	0.1	0.1	0.1	0.2	0.3	0.4	0.6	0.7
		B	F	0.2	0.3	0.3	0.4	0.5	0.7	0.9	1.0
		C	F	0.6	0.7	0.9	1.0	1.1	1.3	1.5	1..8
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 0.3	A	F	0.1	0.1	0.1	0.2	0.3	0.3	0.5	0.6
		B	F	0.1	0.1	0.3	0.4	0.5	0.6	0.8	0.9
		C	F	0.6	0.7	0.9	1.0	1.1	1.3	1.5	1.8
		D	F	2.6	3.2	3.9	4.5	5.1	5.7	6.3	7.0
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Backslope 8H:1V	0.15	A	F	0.1	0.1	0.2	0.3	0.4	0.4	0.6	0.7
		B	F	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1.0
		C	F	0.6	0.7	0.9	1.0	1.1	1.3	1.5	1.8
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 0.3	A	F	0.1	0.1	0.1	0.2	0.3	0.3	0.5	0.6
		B	F	0.1	0.2	0.2	0.3	0.4	0.6	0.8	0.9
		C	F	0.6	0.7	0.9	1.0	1.1	1.3	1.5	1.8
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Backslopes: Located beyond 10H:1V foreslopes (positive or negative) and beyond parallel flat bottom roadside ditches with ditch bottom 2.5 m wide or greater.

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Backslope 6H:1V	0.15	A	F	0.1	0.1	0.3	0.4	0.5	0.5	1.7	0.8
		B	F	0.3	0.4	0.4	0.5	0.6	0.8	1.0	1.1
		C	F	0.6	0.7	0.9	1.0	1.1	1.3	1.5	1.8
		D	F	2.8	3.6	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 0.5	A	F	0.1	0.1	0.1	0.2	0.3	0.3	0.5	0.6
		B	F	0.1	0.2	0.4	0.5	0.5	0.6	0.8	0.9
		C	F	0.6	0.7	0.9	1.0	1.1	1.3	1.5	1.8
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Backslope 4H:1V	≥ 0.15	A	F	0.1	0.1	0.3	0.4	0.5	0.6	0.8	0.9
		B	F	0.4	0.5	0.5	0.6	0.7	0.9	1.1	1.2
		C	F	0.7	0.8	1.0	1.1	1.3	1.4	1.6	1.7
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Backslope 3H:1V	0.15	A	F	0.2	0.3	0.5	0.6	0.7	0.7	0.9	1.0
		B	F	0.4	0.5	0.7	0.8	0.9	1.1	1.3	1.4
		C	F	0.8	0.9	1.1	1.2	1.4	1.6	1.8	1.9
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 1	A	F	0.3	0.4	0.6	0.7	0.9	1.2	1.3	1.4
		B	F	0.7	0.8	1.0	1.1	1.3	1.5	1.7	1.8
		C	F	1.3	1.4	1.6	1.7	1.9	2.1	2.3	2.4
		D	F	2.9	3.4	3.9	4.4	4.9	5.5	6.0	6.5
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Backslopes: Located beyond 10H:1V foreslopes (positive or negative) and beyond parallel flat bottom roadside ditches with ditch bottom 2.5 m wide or greater.

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Backslope 2H:1V	0.15	A	F	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.7
		B	F	0.7	0.8	1.0	1.1	1.3	1.5	1.7	2.0
		C	F	1.0	1.1	1.3	1.4	1.6	1.9	2.2	2.5
		D	F	2.9	3.4	3.9	4.4	4.9	5.5	6.0	6.5
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	F	0.5	0.6	0.8	0.9	1.1	1.3	1.6	1.9
		B	F	0.9	1.0	1.2	1.3	1.4	1.6	1.9	2.2
		C	F	1.4	1.5	1.7	1.8	1.9	2.1	2.3	2.6
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.1	6.6
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1
	0.6	A	F	0.7	0.8	1.0	1.1	1.3	1.5	1.8	2.1
		B	F	1.1	1.2	1.4	1.5	1.7	1.9	2.1	2.4
		C	F	1.9	2.0	2.2	2.3	2.4	2.6	2.8	3.1
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.1	6.6
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1
	≥ 1.2	A	F	0.8	0.9	1.1	1.2	1.5	1.8	2.1	2.4
		B		1.2	1.3	1.5	1.6	1.8	2.1	2.3	2.6
		C	F	2.0	2.1	2.3	2.4	2.5	2.7	2.9	3.2
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.1	6.6
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Backslopes: Located beyond 10H:1V foreslopes (positive or negative) and beyond parallel flat bottom roadside ditches with ditch bottom 2.5 m wide or greater.

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Backslope 1.5H:1V	0.15	A	F	0.3	0.6	0.8	1.1	1.4	1.8	2.2	2.6
		B	F	0.6	0.9	1.1	1.4	1.7	2.1	2.5	2.9
		C	F	0.9	1.2	1.4	1.7	2.1	2.5	3.0	3.5
		D	F	2.9	3.4	3.9	4.4	1.9	5.5	6.0	6.5
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	F	0.5	0.8	1.0	1.3	1.6	2.0	2.6	3.1
		B	F	0.9	1.2	1.4	1.7	1.9	2.3	2.9	3.4
		C	F	1.4	1.7	1.9	2.2	2.4	2.8	3.3	3.8
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.1	6.6
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1
	0.6	A	F	0.9	1.1	1.3	1.5	1.8	2.2	2.7	3.2
		B	F	1.3	1.5	1.7	1.9	2.2	2.6	3.1	3.6
		C	F	2.1	2.3	2.5	2.7	2.9	3.2	3.8	4.3
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.1	6.6
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1
	≥ 1.2	A	F	1.0	1.2	1.4	1.6	2.0	2.4	2.8	3.2
		B	F	1.4	1.6	1.8	2.0	2.3	2.7	3.2	3.7
		C	F	2.2	2.4	2.6	2.8	3.0	3.4	3.9	4.4
		D	F	3.1	3.6	4.1	4.6	5.1	5.7	6.2	6.7
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Backslopes: Located beyond 10H:1V foreslopes (positive or negative) and beyond parallel flat bottom roadside ditches with ditch bottom 2.5 m wide or greater.

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Backslope 1H:1V	0.15	A	F	0.4	0.7	1.0	1.3	1.7	2.2	2.8	3.3
		B	F	0.7	1.0	1.3	1.6	2.0	2.5	3.1	3.6
		C	F	1.0	1.3	1.6	1.9	2.4	2.9	3.5	4.2
		D	F	2.9	3.4	3.9	4.4	4.9	5.5	6.0	6.5
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	F	0.7	1.0	1.3	1.6	2.0	2.4	3.1	3.8
		B	F	1.1	1.4	1.7	2.0	2.3	2.7	3.4	4.1
		C	F	1.6	1.9	2.2	2.5	2.8	3.2	3.8	4.5
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.1	6.6
		E	F	3.3	3.7	4.1	4.6	5.1	5.8	6.4	7.1
	0.6	A	F	1.0	1.3	1.5	1.8	2.2	2.6	3.3	4.0
		B	F	1.4	1.7	1.9	2.2	2.6	3.0	3.6	4.1
		C	F	2.2	2.5	2.7	3.0	3.2	3.6	4.2	4.9
		D	F	3.0	3.5	4.0	4.5	5.0	5.6	6.1	6.6
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1
	≥ 1.2	A	F	1.1	1.4	1.6	1.9	2.3	2.8	3.4	3.9
		B	F	1.5	1.8	2.0	2.3	2.7	3.1	3.7	4.2
		C	F	2.3	2.6	2.8	3.1	3.4	3.8	4.4	4.9
		D	F	3.1	3.6	4.1	4.6	5.1	5.7	6.2	6.7
		E	F	3.3	3.7	4.1	4.6	5.2	5.8	6.4	7.1

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Backslopes Located beyond 10H:1V foreslopes (positive or negative) and beyond parallel flat bottom roadside ditches with ditch bottom 2.5 m wide or greater.

Object Type and Characteristics			Object Surface (*)	Severity Index, SI							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Backslope Vertical ***	0.15	A	F	0.5	0.8	1.1	1.4	1.9	2.4	3.0	3.7
		B	F	0.8	1.1	1.4	1.7	2.2	2.7	3.3	4.0
		C	F	1.1	1.4	1.7	2.0	2.5	3.1	3.8	4.5
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	F	0.7	1.0	1.3	1.6	2.0	2.5	3.2	3.9
		B	F	1.1	1.4	1.7	2.0	2.4	2.8	3.5	4.2
		C	F	1.6	1.9	2.2	2.5	2.9	3.3	3.9	4.6
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.6	A	F	1.0	1.3	1.6	1.9	2.2	2.6	3.2	3.9
		B	F	1.1	1.4	1.7	2.0	2.3	2.7	3.3	4.0
		C	F	1.6	1.9	2.2	2.5	2.8	3.2	3.8	4.3
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 1.0	A	F	1.0	1.3	1.6	1.9	2.2	2.6	3.2	3.9
		B	F	1.0	1.3	1.6	1.9	2.2	2.6	3.2	3.9
		C	F	1.5	1.8	2.1	2.4	2.7	3.1	3.7	4.2
		D	F	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	F	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2
*** Relatively smooth uniform rock cut face = Surface Condition A Jagged rock cut face = Surface Condition E

Parallel Roadside V-Ditches **

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Foreslope	Backslope	Depth (m)		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
2H:1V	2H:1V	0.15	F	1.2	1.5	1.7	2.0	2.4	2.8	3.4	3.9
		0.3	F	1.7	1.8	2.0	2.1	2.5	2.9	3.5	4.0
		0.6	F	1.9	2.0	2.2	2.3	2.7	3.1	3.6	4.1
		1.0	F	2.0	2.1	2.3	2.4	2.7	3.1	3.6	4.1
		1.2	F	2.1	2.2	2.4	2.5	2.8	3.2	3.7	4.2
	3H:1V	0.15	F	1.1	1.4	1.6	1.9	2.2	2.6	3.1	3.6
		0.3	F	1.5	1.7	1.9	2.1	2.4	2.8	3.2	3.6
		0.6	F	1.8	1.9	2.1	2.2	2.5	2.9	3.4	3.9
		1.0	F	1.9	2.0	2.2	2.3	2.5	2.9	3.5	4.0
		1.2	F	2.0	2.1	2.3	2.4	2.6	3.0	3.6	4.1
3H:1V	2H:1V	0.15	F	1.2	1.5	1.7	2.0	2.4	2.8	3.4	3.9
		0.3	F	1.6	1.7	1.9	2.0	2.4	2.8	3.4	3.9
		0.6	F	1.9	2.0	2.0	2.1	2.5	2.9	3.4	3.9
		1.0	F	2.0	2.1	2.1	2.2	2.5	2.9	3.4	3.9
		1.2	F	2.1	2.2	2.2	2.3	2.6	3.0	3.4	3.8
	3H:1V	0.15	F	1.1	1.4	1.6	1.9	2.2	2.6	3.1	3.6
		0.3	F	1.4	1.6	1.8	2.0	2.3	2.7	3.1	3.5
		0.6	F	1.7	1.8	2.0	2.1	2.3	2.7	3.1	3.5
		1.0	F	1.8	1.9	2.1	2.2	2.4	2.7	3.1	3.5
		1.2	F	2.0	2.1	2.1	2.2	2.4	2.8	3.2	3.6
	4H:1V	0.15	F	1.1	1.3	1.5	1.7	1.9	2.3	2.7	3.1
		0.3	F	1.3	1.5	1.7	1.9	2.1	2.4	2.8	3.2
		0.6	F	1.6	1.7	1.9	2.0	2.2	2.4	2.8	3.2
		1.0	F	1.9	2.0	2.0	2.1	2.2	2.5	2.9	3.3
		1.2	F	1.8	1.9	2.1	2.2	2.3	2.5	2.9	3.3

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** For ditch configurations where the ditch bottom is 2.5 m wide or greater, the foreslope and backslope should be treated as independent features with offsets adjusted for intervening slopes. The estimated Severity Indices in this table assumes rounding is insufficient to have a beneficial effect

Parallel Roadside V-Ditches ** (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Foreslope	**Backslope**	**Depth (m)**		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
4H:1V	2H:1V	0.15	F	1.1	1.4	1.6	1.9	2.3	2.7	3.2	3.7
		0.3	F	1.1	1.4	1.6	1.9	2.3	2.7	3.2	3.7
		0.6	F	1.2	1.5	1.7	2.0	2.3	2.7	3.2	3.7
		1.0	F	1.2	1.5	1.7	2.0	2.3	2.7	3.1	3.5
		1.2	F	1.2	1.5	1.7	2.0	2.3	2.7	3.1	3.5
	3H:1V	0.15	F	1.0	1.2	1.4	1.6	1.9	2.3	2.7	3.1
		0.3	F	1.1	1.3	1.5	1.7	1.9	2.3	2.7	3.1
		0.6	F	1.0	1.3	1.5	1.8	2.0	2.3	2.7	3.1
		1.0	F	1.1	1.4	1.6	1.9	2.1	2.3	2.7	3.1
		1.2	F	1.1	1.4	1.7	2.0	2.1	2.3	2.7	3.1
	4H:1V	0.15	F	0.9	1.1	1.3	1.5	1.7	2.0	2.3	2.6
		0.3	F	1.0	1.2	1.4	1.6	1.8	2.1	2.3	2.6
		0.6	F	1.1	1.3	1.5	1.7	1.9	2.2	2.4	2.5
		1.0	F	1.0	1.3	1.5	1.8	2.0	2.2	2.4	2.7
		1.2	F	1.1	1.4	1.6	1.9	2.1	2.3	2.5	2.6

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** For ditch configurations where the ditch bottom is 2.5 m wide or greater, the foreslope and backslope should be treated as independent features with offsets adjusted for intervening slopes. The estimated Severity Indices in this table assumes rounding is insufficient to have a beneficial effect

Parallel Roadside V-Ditches ** (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Foreslope	Backslope	Depth (m)		50	60	70	80	90	100	110	120
6H:1V (cont.)	2H:1V	0.15	F	0.8	1.1	1.3	1.6	2.0	2.4	2.9	3.4
		0.3	F	0.8	1.1	1.3	1.6	2.0	2.4	2.9	3.4
		0.6	F	0.7	1.0	1.2	1.5	1.9	2.3	2.7	3.1
		1.0	F	0.6	0.9	1.1	1.4	1.4	1.8	2.2	2.5
		1.2	F	0.6	0.9	1.1	1.4	1.8	2.2	2.4	2.7
	3H:1V	0.15	F	0.7	0.9	1.1	1.3	1.6	1.9	2.2	2.5
		0.3	F	0.7	0.9	1.1	1.3	1.6	1.9	2.2	2.5
		0.6	F	0.7	0.9	1.1	1.3	1.6	1.9	2.2	2.5
		1.0	F	0.5	0.8	1.0	1.3	1.6	1.9	2.1	2.4
		1.2	F	0.5	0.8	1.0	1.3	1.6	1.9	2.1	2.4
	4H:1V	0.15	F	0.5	0.7	0.9	1.1	1.3	1.6	1.9	2.2
		0.3	F	0.4	0.7	0.9	1.2	1.4	1.7	1.9	2.2
		0.6	F	0.6	0.8	1.0	1.2	1.4	1.7	1.9	2.2
		1.0	F	0.6	0.8	1.0	1.2	1.5	1.8	2.0	2.1
		1.2	F	0.6	0.8	1.0	1.2	1.5	1.8	2.0	2.1
	6H:1V	0.15	F	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.6
		0.3	F	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.7
		0.6	F	0.6	0.7	0.9	1.0	1.2	1.5	1.7	2.0
		1.0	F	0.5	0..7	0.9	1.1	1.3	1.6	1.8	2.1
		1.2	F	0.4	0.7	0.9	1.2	1.4	1.6	1.9	2.2

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** For ditch configurations where the ditch bottom is 2.5 m wide or greater, the foreslope and backslope should be treated as independent features with offsets adjusted for intervening slopes. The estimated Severity Indices in this table assumes rounding is insufficient to have a beneficial effect

Intersecting Slopes – Negative (down)

Object Type and Characteristics			Object Surface (*)	Severity Index – Design Speed – km/h							
Slope (H:V)	**Height (m)**	**Surface Condition (**)**		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Inter-secting Slopes (negative) 10H:1V	0.3	A	S	0.7	0.8	1.0	1.1	1.4	1.7	2.0	2.3
		B	S	0.9	1.0	1.2	1.3	1.4	1.6	2.2	2.9
		C	S	1.2	1.4	1.6	1.8	1.9	2.1	2.8	3.5
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 1.0	A	S	0.6	0.8	1.0	1.2	1.5	1.9	2.3	2.7
		B	S	0.8	1.0	1.2	1.4	1.7	2.1	2.6	3.1
		C	S	1.1	1.4	1.6	1.9	2.2	2.6	3.2	3.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Inter-Secting Slope (negative) 8H:1V	0.3	A	S	1.3	1.4	1.6	1.7	1.9	2.1	2.4	2.7
		B	S	1.5	1.6	1.8	1.9	2.1	2.3	2.7	3.1
		C	S	1.8	2.0	2.2	2.4	2.6	2.9	3.3	3.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	1	A	S	1.4	1.6	1.8	2.0	2.2	2.5	3.0	3.5
		B	S	1.6	1.8	2.0	2.2	2.4	2.7	3.3	3.8
		C	S	1.9	2.2	2.4	2.7	2.9	3.2	3.8	4.5
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	2	A	S	1.4	1.6	1.8	2.0	2.3	2.7	3.2	3.7
		B	S	1.6	1.8	2.0	2.2	2.5	2.9	3.5	4.0
		C	S	1.9	2.2	2.4	2.7	3.0	3.4	4.0	4.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2.

Intersecting Slopes – Negative (down)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 8H:1V	≥ 4	A	S	1.4	1.6	1.8	2.0	2.3	2.7	3.3	3.8
		B	S	1.6	1.8	2.0	2.2	2.5	2.9	3.5	4.2
		C	S	1.9	2.2	2.4	2.7	3.0	3.4	4.1	4.8
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Inter-Secting Slope (negative) 6H:1V	0.3	A	S	1.7	1.8	2.0	2.1	2.3	2.5	2.7	3.0
		B	S	1.9	2.0	2.2	2.3	2.5	2.7	3.0	3.3
		C	S	2.2	2.4	2.6	2.8	3.0	3.2	3.6	4.0
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	1	A	S	2.1	2.3	2.5	2.7	2.9	3.3	3.7	4.1
		B	S	2.3	2.5	2.7	2.9	3.1	3.5	4.0	4.5
		C	S	2.6	2.9	3.1	3.4	3.6	4.0	4.6	5.1
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	2	A	S	2.3	2.6	2.9	3.2	3.5	3.9	4.4	4.9
		B	S	2.5	2.8	3.1	3.4	3.7	4.1	4.7	5.2
		C	S	2.8	3.1	3.5	3.9	4.2	4.6	5.2	5.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	4	A	S	2.2	2.5	2.9	3.3	3.7	4.2	4.8	5.3
		B	S	2.4	2.7	3.1	3.5	3.9	4.4	5.0	5.5
		C	S	2.7	3.1	3.5	4.0	4.4	4.9	5.5	6.0
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 6H:1V	6	A	S	2.2	2.5	2.9	3.3	3.7	4.2	4.9	5.5
		B	S	2.4	2.7	3.1	3.5	3.9	4.4	5.0	5.6
		C	S	2.7	3.1	3.5	4.0	4.4	4.9	5.5	6.0
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 8	A	S	2.2	2.5	2.9	3.3	3.7	4.2	4.9	5.6
		B	S	2.4	2.7	3.1	3.5	3.9	4.4	5.0	5.7
		C	S	2.7	3.1	3.5	4.0	4.4	4.9	5.5	6.0
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
Inter-Secting Slope (negative) 4H:1V	0.3	A	S	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
		B	S	2.1	2.2	2.4	2.5	2.7	2.9	3.2	3.5
		C	S	2.4	2.6	28	3.0	3.2	3.4	3.8	4.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	1	A	S	2.6	2.8	3.0	3.2	3.4	3.6	4.0	4.4
		B	S	2.8	3.0	3.2	3.4	3.6	3.9	4.3	4.7
		C	S	3.1	3.4	3.6	3.9	4.1	4.4	4.9	5.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	2	A	S	3.5	3.7	3.9	4.1	4.3	4.6	5.0	5.4
		B	S	3.6	3.8	4.0	4.2	4.5	4.8	5.2	5.6
		C	S	3.8	4.1	4.3	4.6	5.0	5.3	5.7	6.1
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2.

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 4H:1V (cont.)	4	A	S	3.7	4.1	4.5	5.0	5.2	5.5	5.9	6.3
		B	S	3.8	4.2	4.6	5.1	5.4	5.7	6.1	6.5
		C	S	4.0	4.5	5.0	5.5	5.8	6.2	6.6	7.0
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	6	A	S	3.7	4.3	4.8	5.4	5.9	6.4	6.8	7.2
		B	S	3.8	4.4	4.9	5.5	6.1	6.6	7.0	7.4
		C	S	3.9	4.5	5.2	5.8	6.4	7.0	7.4	7.8
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	8	A	S	3.7	4.3	4.8	5.4	6.0	6.6	7.2	7.7
		B	S	3.8	4.4	4.9	5.5	6.2	6.8	7.3	7.8
		C	S	3.9	4.5	5.2	5.8	6.5	7.1	7.5	7.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	10	A	S	3.7	4.3	4.8	5.4	6.0	6.6	7.2	7.9
		B	S	3.8	4.4	4.9	5.5	6.2	6.8	7.4	7.9
		C	S	3.9	4.5	5.2	5.8	6.5	7.1	7.5	7.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥14	A	S	3.7	4.3	4.8	5.4	6.0	6.6	7.2	7.9
		B	S	3.8	4.4	4.9	5.5	6.2	6.8	7.4	7.9
		C	S	3.9	4.5	5.2	5.8	6.5	7.1	7.5	7.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 3H:1V	0.3	A	S	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
		B	S	2.1	2.2	2.4	2.5	2.7	2.9	3.2	3.5
		C	S	2.4	2.6	2.8	3.0	3.2	3.4	3.8	4.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	1	A	S	2.7	2.9	3.1	3.3	3.5	3.7	4.0	4.3
		B	S	2.7	3.0	3.2	3.5	3.6	3.9	4.3	4.7
		C	S	3.1	3.4	3.6	3.9	4.1	4.4	4.9	5.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	2	A	S	3.8	4.0	4.2	4.4	4.6	4.8	5.1	5.4
		B	S	3.9	4.1	4.3	4.5	4.7	5.0	5.3	5.6
		C	S	4.2	4.4	4.6	4.8	5.0	5.3	5.6	5.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	4	A	S	4.8	5.0	5.2	5.4	5.7	6.0	6.2	6.5
		B	S	4.9	5.1	5.3	5.5	5.9	6.2	6.4	6.7
		C	S	5.1	5.3	5.5	5.7	6.1	6.4	6.8	7.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	6	A	S	4.9	5.3	5.7	6.1	6.4	6.7	6.9	7.2
		B	S	5.0	5.4	5.8	6.2	6.6	6.9	7.1	7.4
		C	S	5.2	5.6	5.9	6.3	6.7	7.0	7.3	7.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2.

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 3H:1V (cont.)	8	A	S	5.0	5.6	6.1	6.7	7.0	7.3	7.5	7.8
		B	S	5.1	5.7	6.2	6.8	7.2	7.5	7.7	8.0
		C	S	5.2	5.8	6.3	6.9	7.3	7.6	7.8	8.1
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	10	A	S	4.9	5.6	6.3	7.0	7.4	7.8	8.2	8.6
		B	S	5.0	5.7	6.4	7.1	7.5	7.9	8.3	8.7
		C	S	5.1	5.8	6.5	7.2	7.6	8.0	8.4	8.8
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	14	A	S	4.9	5.6	6.3	7.0	7.5	7.9	8.3	8.7
		B	S	5.0	5.7	6.4	7.1	7.5	7.9	8.3	8.7
		C	S	5.1	5.8	6.5	7.2	7.6	8.0	8.4	8.8
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 18	A	S	4.9	5.6	6.3	7.0	7.5	8.0	8.4	8.8
		B	S	5.0	5.7	6.4	7.1	7.6	8.0	8.4	8.8
		C	S	5.1	5.8	6.5	7.2	7.6	8.0	8.4	8.8
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2.

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 2H:1V	0.3	A	S	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
		B	S	2.1	2.2	2.4	2.5	2.7	2.9	3.2	3.5
		C	S	2.4	2.6	2.8	3.0	3.2	3.4	3.8	4.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	1	A	S	2.9	3.0	3.2	3.3	3.5	3.7	4.0	4.3
		B	S	2.9	3.1	3.3	3.5	3.6	3.9	4.3	4.7
		C	S	3.3	3.5	3.7	3.9	4.1	4.4	4.9	5.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	2	A	S	4.1	4.2	4.4	4.5	4.7	4.9	5.1	5.4
		B	S	4.1	4.2	4.4	4.5	4.7	5.0	5.3	5.6
		C	S	4.2	4.4	4.6	4.8	5.0	5.3	5.6	5.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	4	A	S	5.5	5.6	5.6	5.7	5.9	6.2	6.4	6.5
		B	S	5.5	5.6	5.6	5.7	6.0	6.3	6.5	6.6
		C	S	5.6	5.7	5.7	5.8	6.1	6.4	6.6	6.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	6	A	S	3.0	6.2	6.4	6.6	6.8	7.1	7.3	7.4
		B	S	6.0	6.2	6.4	6.6	6.9	7.2	7.4	7.5
		C	S	6.1	6.3	6.5	6.7	7.0	7.3	7.5	7.6
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2.

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 2H:1V (cont.)	8	A	S	6.5	6.8	7.1	7.4	7.6	7.9	8.1	8.2
		B	S	6.5	6.8	7.1	7.4	7.7	8.0	8.2	8.3
		C	S	6.6	6.9	7.2	7.5	7.8	8.1	8.3	8.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	10	A	S	7.0	7.4	7.8	8.3	8.5	8.7	8.9	9.0
		B	S	7.0	7.4	7.8	8.3	8.5	8.8	9.0	9.1
		C	S	7.1	7.5	7.9	8.4	8.6	8.9	9.1	9.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	14	A	S	7.2	7.6	8.0	8.5	8.7	9.0	9.2	9.3
		B	S	7.2	7.6	8.0	8.5	8.7	9.0	9.2	9.3
		C	S	7.2	7.6	8.0	8.5	8.7	9.0	9.2	9.3
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	18	A	S	7.3	7.7	8.1	8.6	8.9	9.1	9.3	9.4
		B	S	7.3	7.7	8.1	8.6	8.9	9.1	9.3	9.4
		C	S	7.3	7.7	8.1	8.6	8.9	9.1	9.3	9.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 22	A	S	7.2	7.7	8.2	8.7	8.9	9.1	9.3	9.4
		B	S	7.2	7.7	8.2	8.7	8.9	9.1	9.3	9.4
		C	S	7.2	7.7	8.2	8.7	8.9	9.1	9.3	9.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2.

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (negative) 1½H:1V	0.3	A	S	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
		B	S	2.1	2.2	2.4	2.5	2.7	2.9	3.2	3.5
		C	S	2.4	2.6	2.8	3.0	3.2	3.4	3.8	4.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	1	A	S	2.9	3.0	3.2	3.3	3.5	3.7	4.0	4.3
		B	S	2.9	3.1	3.3	3.5	6.3	3.9	4.3	4.7
		C	S	3.3	3.5	3.7	3.9	4.1	4.4	4.9	5.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	2	A	S	4.1	4.2	4.4	4.5	4.7	4.9	5.1	5.4
		B	S	4.1	4.2	4.4	4.5	4.7	5.0	5.3	5.6
		C	S	4.2	4.4	4.6	4.8	5.0	5.3	5.6	5.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	4	A	S	5.6	5.7	5.7	5.8	6.0	6.2	6.4	6.5
		B	S	5.6	5.7	5.7	5.8	6.0	6.3	6.5	6.6
		C	S	5.5	5.6	5.8	5.9	6.1	6.4	6.6	6.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	6	A	S	6.3	6.5	6.6	6.7	6.9	7.1	7.4	7.4
		B	S	6.3	6.5	6.6	6.7	6.9	7.2	7.4	7.5
		C	S	6.3	6.5	6.6	6.7	6.9	7.2	7.4	7.5
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2

Intersecting Slopes – Negative (down) (continued)

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	**Height (m)**	**Surface Condition (**)**		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Inter-secting Slopes (negative) 1½H:1V (cont.)	8	A	S	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.3
		B	S	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.3
		C	S	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.3
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	10	A	S	7.9	8.2	8.5	8.8	8.9	8.9	9.1	9.2
		B	S	7.9	8.2	8.5	8.8	8.9	8.9	9.1	9.2
		C	S	7.9	8.2	8.5	8.8	8.9	8.9	9.1	9.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	14	A	S	8.3	8.6	8.8	9.1	9.2	9.3	9.5	9.6
		B	S	8.3	8.6	8.8	9.1	9.2	9.3	9.5	9.6
		C	S	8.3	8.6	8.8	9.1	9.2	9.3	9.5	9.6
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	18	A	S	8.5	8.8	9.0	9.3	9.4	9.5	9.5	9.5
		B	S	8.5	8.8	9.0	9.3	9.4	9.5	9.5	9.5
		C	S	8.5	8.8	9.0	9.3	9.4	9.5	9.5	9.5
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥ 22	A	S	8.6	8.9	9.1	9.4	9.5	9.5	9.6	9.6
		B	S	8.6	8.9	9.1	9.4	9.5	9.5	9.6	9.6
		C	S	8.6	8.9	9.1	9.4	9.5	9.5	9.6	9.6
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F
** See Table A-2.

Intersecting Slopes – Vertical Drop With and Without Water Present

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	**Height (m)**	**Water Depth (m)**		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Inter-secting Slopes (negative) Vertical Drop	0.0	0	S	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8
		1	S	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.7
		2	S	4.3	4.6	4.8	5.1	5.3	5.6	5.8	6.1
		4	S	6.0	6.2	6.4	6.6	6.8	7.0	7.2	7.5
		≥6	S	7.5	7.7	7.9	8.1	8.3	8.4	8.6	8.7
	0.3	0	S	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
		1	S	2.6	2.9	3.1	3.4	3.6	3.9	4.1	4.4
		2	S	4.3	4.6	4.9	5.2	5.6	5.9	6.3	6.7
		4	S	6.0	6.3	6.6	6.9	7.1	7.4	7.6	7.9
		≥6	S	7.9	8.0	8.2	8.3	8.5	8.7	8.9	9.0
	1	0	S	2.9	3.0	3.2	3.3	3.5	3.7	4.0	4.3
		1	S	3.2	3.4	3.6	3.8	4.0	4.2	4.5	4.8
		2	S	5.4	5.6	5.8	6.0	6.3	6.6	6.8	7.1
		4	S	6.5	6.8	7.0	7.3	7.5	7.7	7.9	8.2
		≥6	S	8.0	8.1	8.3	8.4	8.6	8.8	9.0	9.1
	2	0	S	4.1	4.2	4.4	4.5	4.7	4.9	5.1	5.4
		1	S	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.7
		2	S	6.5	6.6	6.8	6.9	7.1	7.3	7.5	7.6
		4	S	7.3	7.4	7.6	7.7	7.9	8.1	8.3	8.4
		≥6	S	8.1	8.2	8.4	8.5	8.7	8.9	9.1	9.2
	4	0	S	5.7	5.8	5.8	5.9	6.0	6.2	6.4	6.5
		1	S	5.7	5.8	6.0	6.1	6.2	6.4	6.7	7.0
		2	S	7.2	7.3	7.5	7.6	7.8	8.0	8.2	8.3
		4	S	7.8	7.9	8.1	8.2	8.4	8.6	8.8	8.9
		≥6	S	8.4	8.5	8.7	8.8	9.0	9.2	9.4	9.5
	≥8	Any Depth	S	Use Values From Foreslopes - Vertical							

*S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

Intersecting Slopes – Positive (up) ***

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (positive) 10H:1V	0.15	A	S	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.6
		B	S	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.8
		C	S	0.9	1.0	1.2	1.3	1.5	1.7	2.0	2.3
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	S	0.4	0.5	0.7	0.8	1.2	1.5	1.9	2.3
		B	S	0.6	0.7	0.9	1.0	1.4	1.7	2.1	2.5
		C	S	0.8	1.0	1.2	1.4	1.8	2.1	25	2.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥0.6	A	S	0.4	0.5	0.7	0.8	1.2	1.6	2.0	2.4
		B	S	0.6	0.7	0.9	1.0	1.4	1.8	2.2	2.6
		C	S	0.8	1.0	1.2	1.4	1.8	2.2	2.6	3.0
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2.

*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Intersecting Slopes – Positive (up) * (continued)**

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (positive) 8H:1V (cont.)	0.15	A	S	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.6
		B	S	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.8
		C	S	0.9	1.0	1.2	1.3	1.5	1.7	2.0	2.3
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥1	A	S	0.3	0.6	0.9	1.2	1.7	2.1	2.3	2.6
		B	S	0.5	0.8	1.1	1.4	1.8	2.2	2.5	2.8
		C	S	0.7	1.0	1.4	1.8	2.2	2.6	2.9	3.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2.

*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Intersecting Slopes – Positive (up) * (continued)**

Object Type and Characteristics			Object Surface (*)	Severity Index – Design Speed – km/h							
Slope (H:V)	**Height (m)**	**Surface Condition (**)**		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Inter-secting Slopes (positive) 6H:1V (cont.)	0.15	A	S	0.3	0.4	0.6	0.7	0.9	1.1	0.3	1.6
		B	S	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.8
		C	S	0.7	0.9	1.1	1.3	1.5	1.8	2.0	2.3
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	S	0.5	0.8	1.2	1.6	2.0	2.3	2.6	2.9
		B	S	0.7	1.0	1.4	1.8	2.1	2.4	2.8	3.2
		C	S	1.0	1.3	1.7	2.1	2.4	2.7	3.1	3.5
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.6	A	S	0.5	0.9	1.3	1.8	2.1	2.4	2.7	3.0
		B	S	0.8	1.1	1.5	1.9	2.2	2.5	2.9	3.3
		C	S	1.0	1.4	1.8	2.3	2.5	2.8	3.2	3.6
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥1	A	S	0.4	0.9	1.4	1.9	2.2	2.5	2.8	3.1
		B	S	0.7	1.1	1.5	2.0	2.3	2.6	3.0	3.4
		C	S	0.9	1.4	1.9	2.4	2.6	2.9	3.3	3.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2

*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Intersecting Slopes – Positive (up) * (continued)**

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (positive) 4H:1V (cont.)	0.15	A	S	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.7
		B	S	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.9
		C	S	0.6	0.9	1.1	1.4	1.6	1.8	2.1	2.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	S	1.3	1.6	1.9	2.2	2.6	3.0	3.3	3.6
		B	S	1.5	1.8	2.0	2.3	2.7	3.1	3.5	3.9
		C	S	1.8	2.1	2.3	2.6	3.0	3.4	3.8	4.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.6	A	S	1.6	1.9	2.1	2.4	2.8	3.2	3.5	3.8
		B	S	1.7	2.0	2.2	2.5	2.9	3.3	3.6	3.9
		C	S	2.2	2.4	2.6	2.8	3.2	3.6	3.9	4.2
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥1	A	S	1.6	1.9	2.1	2.4	2.8	3.2	3.6	4.0
		B	S	1.7	2.0	2.2	2.5	2.9	3.3	3.7	4.1
		C	S	2.2	2.4	2.6	2.8	3.2	3.6	4.0	4.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2

*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Intersecting Slopes – Positive (up) * (continued)**

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (positive) 3H:1V	0.15	A	S	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.7
		B	S	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.9
		C	S	0.6	0.9	1.1	1.4	1.6	1.8	2.1	2.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	S	1.8	2.1	2.4	2.7	3.1	3.5	3.9	4.3
		B	S	1.9	2.2	2.5	2.8	3.2	3.6	4.0	4.4
		C	S	2.2	2.5	2.8	3.1	3.5	3.9	4.2	4.5
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.6	A	S	1.8	2.1	2.5	2.9	3.3	3.7	4.1	4.5
		B	S	1.9	2.2	2.6	3.0	3.4	3.8	4.2	4.6
		C	S	2.2	2.5	2.9	3.3	3.7	4.0	4.4	4.8
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥1	A	S	1.9	2.2	2.6	3.0	3.4	3.8	4.2	4.6
		B	S	2.0	2.3	2.7	3.1	3.5	3.9	4.3	4.7
		C	S	2.1	2.5	2.9	3.4	3.8	4.1	4.5	4.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2.

*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Intersecting Slopes – Positive (up) * (continued)**

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (positive) 2H:1V	0.15	A	S	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.7
		B	S	0.6	0.7	0.9	1.0	1.2	1.4	1.6	1.9
		C	S	0.8	1.0	1.2	1.4	1.6	1.8	2.1	2.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	S	2.1	2.5	2.9	3.4	3.9	4.4	4.8	5.2
		B	S	2.2	2.6	3.0	3.5	4.0	4.5	4.9	5.3
		C	S	2.3	2.8	3.3	3.8	4.2	4.7	5.1	5.5
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.6	A	S	2.5	2.8	3.2	3.6	4.1	4.6	5.0	5.4
		B	S	2.6	2.9	3.3	3.7	4.2	4.7	5.1	5.5
		C	S	2.8	3.1	3.5	3.9	4.4	4.9	5.3	5.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥1	A	S	2.6	2.9	3.3	3.7	4.2	4.7	5.1	5.5
		B	S	2.7	3.0	3.4	3.8	4.3	4.8	5.2	5.6
		C	S	2.9	3.2	3.6	4.0	4.5	4.9	5.3	5.7
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2

*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Intersecting Slopes – Positive (up) * (continued)**

Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (positive) 1½H:1V	0.15	A	S	0.4	0.5	0.7	0.8	1.0	1.2	1.5	1.8
		B	S	0.6	0.7	0.9	1.0	1.2	1.5	1.7	2.0
		C	S	0.8	1.0	1.2	1.4	1.6	1.9	2.1	2.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	S	2.4	2.9	3.4	3.9	4.3	4.8	5.3	5.8
		B	S	2.5	3.0	3.5	4.0	4.4	4.9	5.4	5.9
		C	S	2.7	3.2	3.7	4.2	4.6	5.1	5.5	5.9
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.6	A	S	2.6	3.1	3.6	4.1	4.6	5.2	5.6	6.0
		B	S	2.7	3.2	3.7	4.2	4.7	5.3	5.7	6.1
		C	S	2.8	3.1	3.5	3.9	4.4	4.9	5.3	5.7
		D	S	2.9	3.4	3.9	4.4	4.9	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	≥1	A	S	2.7	3.2	3.7	4.2	4.7	5.3	5.7	6.1
		B	S	2.8	3.3	3.8	4.3	4.8	5.4	5.8	6.2
		C	S	3.0	3.5	4.0	4.5	5.0	5.5	5.9	6.3
		D	S	3.0	3.5	4.0	4.5	5.0	5.5	5.9	6.3
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2.

*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Intersecting Slopes – Positive (up) * (continued)**

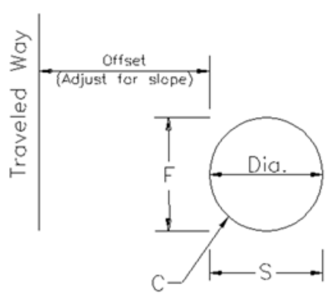
Object Type and Characteristics			Object Surface (*)	Severity Index							
				Design Speed – km/h							
Slope (H:V)	Height (m)	Surface Condition (**)		50	60	70	80	90	100	110	120
Inter-secting Slopes (positive) 1H:1V	0.15	A	S	0.4	0.5	0.7	0.8	1.0	1.3	1.5	1.8
		B	S	0.6	0.7	0.9	1.0	1.2	1.5	1.7	2.0
		C	S	0.8	1.0	1.2	1.4	1.6	1.9	2.1	2.4
		D	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.3	A	S	2.9	3.3	3.7	4.2	4.7	5.3	5.8	6.3
		B	S	3.0	3.4	3.8	4.3	4.8	5.4	5.8	6.2
		C	S	3.2	3.6	4.0	4.5	5.0	5.5	5.9	6.3
		D	S	3.2	3.6	4.0	4.5	5.0	5.5	5.9	6.3
		E	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	7.0
	0.6	A	S	3.0	3.5	4.0	4.5	5.0	5.6	6.2	6.7
		B	S	3.1	3.6	4.1	4.6	5.1	5.6	6.2	6.7
		C	S	3.3	3.8	4.3	4.8	5.2	5.7	6.3	6.8
		D	S	3.3	3.8	4.3	4.8	5.2	5.7	6.3	6.8
		E	S	3.3	3.8	4.3	4.8	5.2	5.7	6.3	7.0
	≥1	A	S	3.1	3.6	4.1	4.6	5.1	5.7	6.3	6.8
		B	S	3.2	3.7	4.2	4.7	5.2	5.7	6.3	6.8
		C	S	3.4	3.9	4.4	4.9	5.3	5.8	6.4	6.9
		D	S	3.4	3.9	4.4	4.9	5.3	5.8	6.4	6.9
		E	S	3.4	3.9	4.4	4.9	5.3	5.8	6.4	7.0

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** See Table A-2

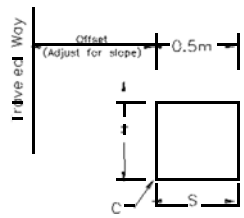
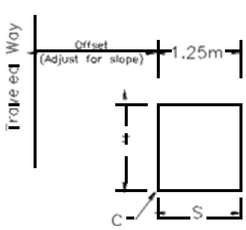
*** The condition addressed in this table is a relatively simple one where the vehicle encounters an intersecting upward slope that connects to a relatively level and wide surface at its upper limit. Transitions between forelope or backslope and intersecting slopes are not addressed, nor is the condition where a vehicle might vault over a dyke or a narrow intersecting roadway. Developing SIs for other conditions will require special analysis and engineering judgment.

Fixed Objects

Object Type and Characteristics		Object Surface (*)	Severity Index							
			Design Speed – km/h							
			50	60	70	80	90	100	110	120
Trees or stumps (diameter measured at 15cm above ground)	Diameter = 50 mm	A	0.2	0.3	0.3	0.4	0.5	0.5	0.7	0.8
	Diameter = 100 mm	A	1.0	1.1	1.1	1.2	1.3	1.5	1.7	2.0
	Diameter = 150 mm	A	2.5	2.6	2.6	2.7	2.9	3.0	3.2	3.3
	Diameter = 200 mm	A	3.2	3.5	3.7	4.0	4.3	4.6	5.0	5.4
	Diameter = 250 mm	A	3.2	3.6	4.0	4.5	5.0	5.6	6.2	6.7
	Diameter = 300 mm	A	3.3	3.7	4.1	4.6	5.1	5.7	6.4	7.1
	Diameter > 300 mm	A	3.4	3.8	4.2	4.7	5.2	5.8	6.5	7.2
Utility Poles	Diameter = 200 mm	A	3.1	3.4	3.6	3.9	4.2	4.5	4.9	5.3
	Diameter = 250 mm	A	3.1	3.5	3.9	4.4	4.9	5.5	6.1	6.6
	Diameter = 300 mm	A	3.3	3.7	4.1	4.6	5.1	5.6	6.3	7.0
	Diameter > 300 mm	A	3.4	3.8	4.2	4.7	5.2	5.8	6.5	7.2
Round 	Diameter = 0.5 m	S	3.0	3.4	3.8	4.3	4.8	5.4	6.0	6.5
		C	3.4	3.8	4.2	4.7	5.2	5.8	6.5	7.2
		F	2.6	3.0	3.4	3.9	4.4	4.9	5.3	5.7
	Diameter = 1.0 m	S	2.8	3.3	3.8	4.3	4.8	5.3	5.9	6.4
		C	3.3	3.7	4.1	4.6	5.1	5.7	6.4	7.1
		F	2.5	2.9	3.3	3.8	4.3	4.7	5.0	5.3
	Diameter > 2.0 m	S	2.7	3.2	3.7	4.2	4.7	5.3	5.9	6.4
		C	3.2	3.6	4.0	4.5	5.0	5.6	6.3	7.0
		F	2.6	2.9	3.3	3.7	4.2	4.7	5.2	5.7

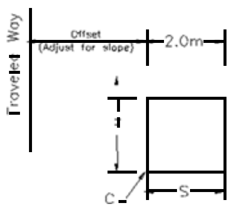
S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

Fixed Objects (continued)

Object Type and Characteristics		Object Surface (*)	Severity Index							
			Design Speed – km/h							
			50	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Rectangular: Width of approach side equal to 0.5 m Face parallel to roadway, sides are perpendicular. 	Height = 0.15 m	S	0.2	0.3	0.5	0.6	0.7	0.8	0.9	0.9
		C	0.2	0.3	0.5	0.6	0.7	0.8	0.9	0.9
		F	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.5
	Height = 0.3 m	S	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		C	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
	Height = 0.5 m	S	3.2	3.6	4.0	4.5	5.1	5.7	6.3	6.8
		C	3.2	3.6	4.0	4.5	5.1	5.7	6.3	6.8
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
	Height = 0.6 m	S	3.4	3.8	4.2	4.7	5.2	5.8	6.5	7.2
		C	3.4	3.8	4.2	4.7	5.2	5.8	6.5	7.2
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
	Height > 1.0 m	S	3.4	3.9	4.4	4.9	5.4	6.0	6.7	7.4
		C	3.4	3.9	4.4	4.9	5.4	6.0	6.7	7.4
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
Rectangular: Width of approach side is 1.25 m. Face is parallel to roadway, sides are perpendicular. 	Height = 0.15 m	S	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.8
		C	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.8
		F	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.5
	Height = 0.3 m	S	2.6	3.2	3.7	4.3	4.8	5.3	5.8	6.3
		C	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
	Height = 0.5 m	S	3.0	3.5	4.0	4.5	5.0	5.6	6.2	6.7
		C	3.2	3.6	4.0	4.5	5.1	5.7	6.3	6.8
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
	Height = 0.6 m	S	3.1	3.6	4.1	4.6	5.1	5.7	6.4	7.1
		C	3.4	3.8	4.2	4.7	5.2	5.8	6.5	7.2
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
	Height > 1.0 m	S	3.3	3.8	4.3	4.8	5.3	5.9	6.6	7.3
		C	3.4	3.9	4.4	4.9	5.4	6.0	6.7	7.4
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2

S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

Fixed Objects (continued)

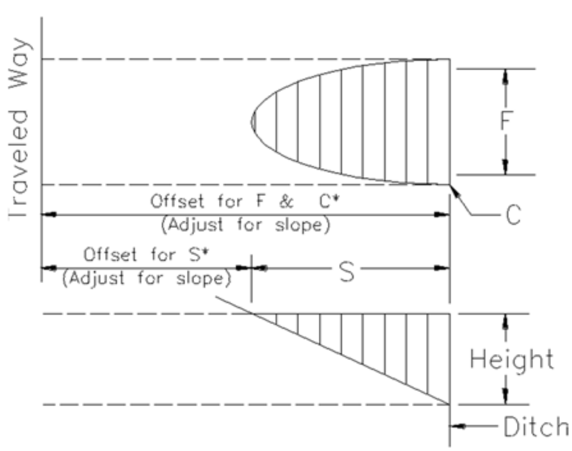
Object Type and Characteristics		Object Surface (*)	Severity Index Design Speed – km/h 50	60	70	80	90	100	110	120
Rectangular: Width of approach side is 2 m or greater. Face is parallel to traffic and sides are perpendicular.	Height = 0.15 m	S	0.5	0.7	0.9	1.1	1.3	1.6	1.9	2.2
		C	0.5	0.7	0.9	1.1	1.3	1.6	1.9	2.2
		F	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.5
	Height = 0.3 m	S	2.5	3.1	3.6	4.2	4.7	5.3	5.8	6.3
		C	2.8	3.3	3.8	4.3	4.8	5.4	5.9	6.4
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.3
	Height = 0.5 m	S	2.9	3.4	3.9	4.4	4.9	5.5	6.1	6.6
		C	3.2	3.6	4.0	4.5	5.1	5.7	6.3	6.8
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2
	Height = 0.6 m	S	2.8	3.4	4.1	4.7	5.1	5.6	6.3	7.0
		C	3.5	3.8	4.2	4.6	5.2	5.8	6.5	7.2
		F	1.9	2.0	2.2	2.3	2.5	2.7	3.0	3.3
	Height > 1.0 m	S	3.2	3.7	4.2	4.7	5.2	5.8	6.5	7.2
		C	3.4	3.9	4.4	4.9	5.4	6.0	6.7	7.4
		F	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.3

S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

Culverts

Object Type and Characteristics		Object Surface (*)	Severity Index							
			Design Speed – km/h							
Description	Height		50	60	70	80	90	100	110	120
Culvert Ends: Culvert Axis Transverse to traffic Culvert End Type A	0.3 m	S	0.4	0.5	0.7	0.8	0.9	1.1	1.3	1.4
		C	1.4	1.7	2.0	2.3	2.7	3.1	3.4	3.7
		F	2.3	2.6	2.9	3.2	3.4	3.7	4.0	4.3
	0.5 m	S	0.6	0.7	0.9	1.0	1.2	1.4	1.6	1.7
		C	1.7	2.1	2.5	3.0	3.4	3.8	4.3	4.8
		F	2.1	2.4	2.8	3.2	3.4	3.6	4.0	4.4
	0.6 m	S	1.5	1.8	2.2	2.6	2.9	3.2	3.6	4.0
		C	1.9	2.5	3.2	3.8	4.3	4.8	5.3	5.8
		F	2.2	2.5	2.8	3.1	3.3	3.6	4.0	4.4
	1.0 m	S	2.1	2.5	2.9	3.4	3.8	4.2	4.7	5.2
		C	2.0	2.6	3.1	3.7	4.3	4.9	5.5	6.0
		F	2.2	2.5	2.8	3.1	3.5	3.8	4.1	4.4
	1.2 m	S	2.6	3.0	3.4	3.9	4.3	4.8	5.4	5.9
		C	1.6	2.2	2.9	3.5	4.2	4.8	5.4	6.1
		F	2.1	2.5	2.9	3.4	3.8	4.1	4.3	4.6
	1.8 m	S	2.9	3.3	3.7	4.2	4.7	5.2	5.8	6.5
		C	1.1	1.8	2.5	3.2	3.9	4.5	5.1	5.8
		F	1.6	2.1	2.6	3.1	3.4	3.8	4.2	4.6
	2.4 m	S	3.0	3.5	4.0	4.5	5.0	5.6	6.2	6.7
		C	0.2	1.0	1.9	2.7	3.4	4.1	4.7	5.4
		F	1.5	1.9	2.3	2.8	3.3	3.7	4.1	4.5

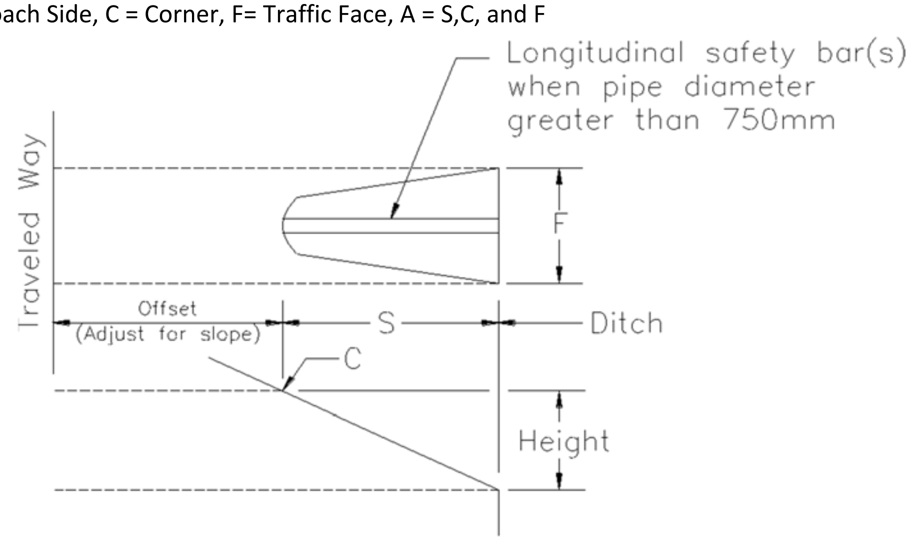
S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F



Culverts (continued)

Object Type and Characteristics		Object Surface (*)	Severity Index							
			Design Speed – km/h							
Description	**Height**		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Culvert Ends: Culvert Axis Transverse to traffic Safety Slope End Treatment per OPSD 801.040, or Concrete Box with Safety Bars. Slope of Treatment matches adjacent 4H:1V or 6H:1V Foreslope	0.3 m	S,C,&F	0.2	0.3	0.5	0.6	0.8	1.0	1.3	1.6
	0.5 m	S,C,&F	0.4	0.5	0.7	0.8	1.2	1.6	2.0	2.4
	0.6 m	S,C,&F	0.3	0.6	0.9	1.2	1.7	2.1	2.3	2.6
	1.0 m	S,C,&F	0.5	1.0	1.5	2.0	2.3	2.6	3.0	3.4
	1.2 m	S,C,&F	1.5	1.8	2.1	2.4	2.8	3.2	3.5	3.6
	1.8 m	S,C,&F	1.9	2.3	2.5	2.8	3.0	3.3	3.5	3.6

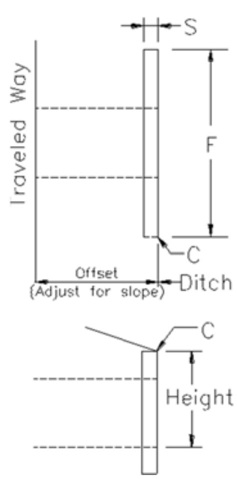
S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F



Culverts (continued)

Object Type and Characteristics		Object Surface (*)	Severity Index							
			Design Speed – km/h							
Description	Height		50	60	70	80	90	100	110	120
Culvert Ends: Culvert Axis Transverse to traffic Culvert Headwall Parallel to Traffic and Tied into Foreslope	0.3 m	C,S	2.4	2.7	3.0	3.3	3.6	3.9	4.3	4.7
		F	2.1	2.4	2.7	3.0	3.3	3.6	3.8	4.1
	0.5 m	C,S	3.0	3.3	3.5	3.8	4.1	4.4	4.6	4.9
		F	2.6	2.9	3.1	3.4	3.6	3.9	4.1	4.4
	0.6 m	C,S	3.2	3.5	3.8	4.1	4.4	4.7	5.0	5.3
		F	2.8	3.1	3.3	3.6	3.8	4.1	4.3	4.6
	1.0 m	C,S	3.9	4.2	4.5	4.8	5.0	5.3	5.5	5.8
		F	3.0	3.3	3.6	3.9	4.1	4.4	4.6	4.9
	1.2 m	C,S	4.3	4.5	4.7	4.9	5.2	5.5	5.8	6.1
		C,S	3.5	3.7	3.9	4.1	4.3	4.6	4.8	5.1
	1.8 m	F	4.8	5.0	5.2	5.4	5.7	6.0	6.3	6.6
		C,S	4.0	4.2	4.4	4.6	4.8	5.1	5.3	5.6
	2.4 m	F	5.2	5.4	5.6	5.8	6.0	6.3	6.6	6.9
		C,S	4.6	4.7	4.9	5.0	5.2	5.5	5.7	6.0

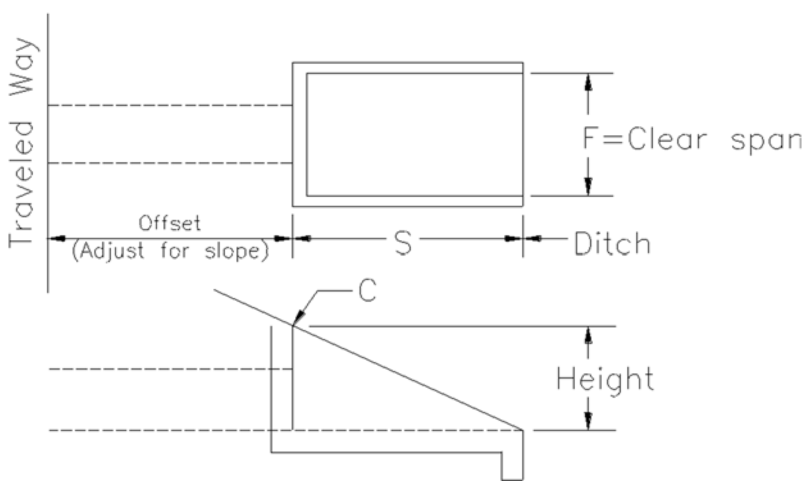
S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F



Culverts (continued)

Object Type and Characteristics		Object Surface (*)	Severity Index							
			Design Speed – km/h							
Description	**Height**		**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**
Culvert Ends: Culvert Axis Transverse to traffic Culvert End with Headwalls perpendicular to Traffic	0.3 m	S,C,&F	1.2	1.4	1.6	1.8	2.0	2.3	2.6	2.9
	0.5 m	S,C,&F	1.5	1.7	1.9	2.1	2.4	2.8	3.5	4.2
	0.6 m	S,C,&F	1.6	1.9	2.1	2.4	2.8	3.1	3.3	3.6
	1.0 m	S,C,&F	1.7	2.1	2.5	3.0	3.2	3.5	3.8	4.1
	1.2 m	S,C,&F	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.5
	1.8 m	S,C,&F	3.0	3.3	3.6	3.9	4.3	4.6	4.9	5.2
	2.4 m	S,C,&F	3.3	3.6	4.0	4.4	4.8	5.1	5.5	5.9

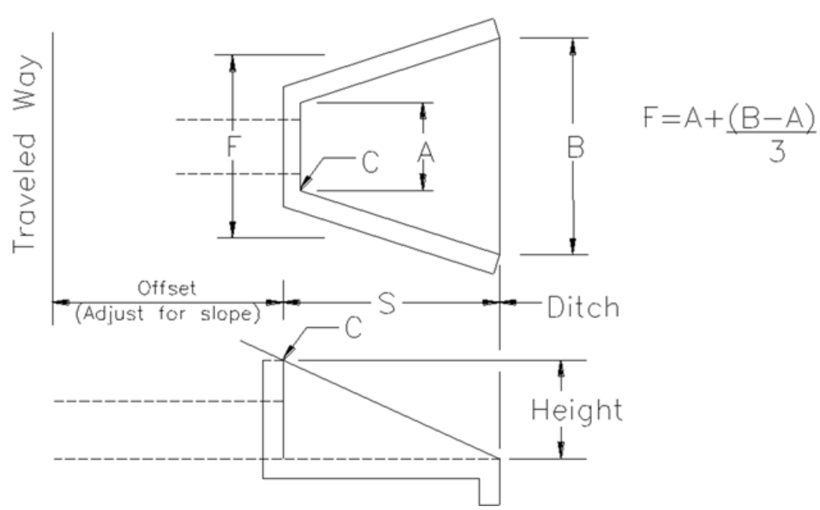
S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F



Culverts (continued)

Object Type and Characteristics		Object Surface (*)	Severity Index							
			Design Speed – km/h							
Description	Height		50	60	70	80	90	100	110	120
Culvert Ends: Culvert Axis Transverse to traffic Culvert End with Wingwalls	0.3 m	S	1.8	2.1	2.3	2.6	2.9	3.1	3.3	3.4
		C	2.2	2.5	2.8	3.1	3.4	3.7	3.9	4.2
		F	1.8	2.0	2.2	2.4	2.7	3.0	3.2	3.3
	0.5 m	S	2.5	2.7	2.9	3.1	3.2	3.4	3.7	4.0
		C	3.0	3.2	3.4	3.6	3.8	4.1	4.3	4.6
		F	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.8
	0.6 m	S	2.6	2.8	3.0	3.2	3.4	3.7	4.0	4.3
		C	3.0	3.3	3.5	3.8	4.0	4.3	4.6	4.9
		F	2.3	2.6	2.8	3.1	3.3	3.5	3.8	4.1
	1.0 m	S	2.7	3.0	3.4	3.8	4.0	4.2	4.4	4.5
		C	3.3	3.6	4.0	4.4	4.6	4.8	5.0	5.3
		F	2.7	3.0	3.3	3.6	3.8	4.0	4.2	4.3
	1.2 m	S	3.3	3.5	3.7	3.9	4.1	4.3	4.6	4.9
		C	3.9	4.1	4.3	4.5	4.7	5.0	5.3	5.6
		F	3.1	3.3	3.5	3.7	3.9	4.1	4.4	4.7
	1.8 m	S	3.9	4.0	4.2	4.3	4.5	4.8	5.1	5.4
		C	4.4	4.6	4.8	5.0	5.2	5.5	5.8	6.1
		F	3.7	3.8	4.0	4.1	4.3	4.6	4.9	5.2
	2.4 m	S	4.3	4.4	4.6	4.7	4.9	5.1	5.2	5.2
		C	5.0	5.1	5.3	5.4	5.6	5.8	6.0	6.1
		F	4.1	4.2	4.4	4.5	4.7	4.9	5.0	5.0

S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F



Barrier Terminals, Attenuators, Breakaway Signs, and Frangible Base Luminaires

Object Type and Characteristics	Object Surface (*)	Severity Index							
		Design Speed – km/h							
		50	60	70	80	90	100	110	120
3-Cable guide rail system on cedar posts.	F	2.0	2.3	2.5	2.8	3.1	3.4	3.6	3.8
High Tension 3-Cable or 4-Cable guide rail systems with steel posts	F	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.6
Semi-rigid steel beam guide rail systems on steel posts: *	F	2.0	2.3	2.5	2.9	3.1	3.4	3.6	3.7
Concrete Barrier systems (Permanent/Embedded) **	F	2.1	2.4	2.6	3.0	3.2	3.5	3.7	3.8
Temporary Concrete Barrier Systems, unrestrained *	F	2.1	2.4	2.6	3.0	3.2	3.5	3.7	3.8
Temporary Concrete Barrier Systems, restrained *	F	2.1	2.4	2.6	3.0	3.2	3.5	3.7	3.8

S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

* NCHRP Report 350 TL-3 or TL-4 systems, and MASH TL-3 Systems

** NCHRP Report 350 and MASH TL-3, TL-4 and TL-5 Systems

Barrier Terminals, Attenuators, Breakaway Signs, and Frangible Base Luminaires (continued),

Object Type and Characteristics	Object Surface (*)	Severity Index							
		Design Speed – km/h							
		50	**60**	**70**	**80**	**90**	**100**	**110**	**120**
High tension Cable Guide Rail Terminal	F	2.0	2.3	2.5	2.8	3.0	3.3	3.5	3.6
	C&S	1.8	2.0	2.2	2.4	2.5	2.7	2.9	3.2
Steel Beam or Box Beam Energy Attenuating Terminals (e.g., SBEAT, SBT, BB-BEAT, QuadTrend) ***	F (**)	2m @ 2.1	2m @ 2.3	2m @ 2.5	2m @ 2.7	2m @ 2.9	2m @ 3.2	2m @ 3.5	2m @ 3.8
	C&S	2.1	2.3	2.5	2.7	2.9	3.2	3.5	3.8
Energy Attenuator Terminals for Concrete Barrier - Temporary and Permanent installations ****	F	2.1	2.3	2.5	2.7	2.9	3.2	3.5	3.8
	C&S	2.1	2.3	2.5	2.7	2.9	3.2	3.5	3.8
Breakaway Sign Support Systems **	A	1.8	2.0	2.2	2.4	2.5	2.7	2.9	3.2
Frangible Base Luminaire Poles ***	A	1.9	2.2	2.4	2.6	2.8	3.0	3.3	3.4

* S = Approach Side, C = Corner, F= Traffic Face, A = S,C, and F

** Dimension above “@” sign is length of device at impact end of system to be analyzed using the noted severity index.

*** NCHRP Report 350 or MASH TL-3 Systems

**** NCHRP Report 350 TL-2 systems for low speed installations with posted speeds < 70km/h, and TL-3 systems for high-speed installations with posted speeds ≥ 70km/h.

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Appendix B: Glossary

This glossary is applicable for all chapters of TAC Geometric Design Guide for Canadian Roads – June 2017 the MTO Design Supplement and the Roadside Design Manuals:

TERM	DEFINITION / DESCRIPTION
85th Percentile Speed	The speed at or below which 85 percent of all observed traffic is traveling at a particular point or segment
Acceleration Lane	An auxiliary lane to enable a vehicle entering a roadway to increase speed to merge with through traffic as applied at channelized intersections, or as speed-change lane at interchanges.
Access Control	See "Controlled Access"
Access Management	The management of the location and basic dimensions of access to property, from a roadway.
Accident	Not used. (See "Collision")
Adverse Crown[a]	A section with the cross-slope removed to a zero slope. This change in cross-slope is accomplished over the tangent runout.
Advisory Speed	The speed displayed on an advisory speed plaque and determined on the basis of an engineering analysis
Alternating One-way Operation[b]	A construction work zone mitigation strategy used on two-way roadways wherein opposing directions of travel take turns using a single travel lane. Flaggers, with or without pilot vehicles; STOP signs; or signals are normally used to coordinate the two directions of traffic. This strategy compensates for the removal of permanent travel lanes from service and is sometimes referred to as one-lane, two-way operation.
Ancillary Space	The part of the roadway, between the travel lanes and the curb or pavement edge.
Annual Average Daily Traffic[b] (AADT)	The total volume of traffic passing a point or segment of a highway in both directions for 1 year divided by the number of days in the year.
Approach Nose	The end of a median or island that faces approaching traffic.
Approach Taper	The taper required in advance of an intersection to shift the through lanes laterally to the right to provide the width for a left-turn auxiliary lane.
Area of Concern[b]	An area within the roadside environment and within the desirable clear zone that has a higher severity index than a barrier system.
Area of Contents	An object or roadside condition that may warrant safety treatment.
Arterial Road	A road primarily for through traffic.
Assumed Speed[b]	The assumed speed for calculating minimum stopping sight distance is based on the 85th percentile wet weather speeds as derived from a traffic study.
Assured Passing Opportunity[b]	A condition in which a vehicle can safely pass another without restriction either by visibility or opposing traffic.
Auxiliary Lane[a]	A lane in addition to, and placed adjacent to, a through lane intended for a specific maneuver such as turning, merging, diverging, weaving, and for slow vehicles, but not parking.

TERM	DEFINITION / DESCRIPTION
Average Annual Daily Traffic (AADT)	The total volume of traffic passing a point or segment of a roadway, in both directions for one year, divided by the number of days in the year.
Average Daily Traffic[b] (ADT)	The total volume of traffic during a given time period (in whole days) greater than one day and less than one year divided by the number of days in that time period.
Back Slope[b]	Where the roadway is in cut, the slope between the drainage channel and the natural ground is referred to as a back slope.
Barrier[b]	A device which provides a physical limitation through which a vehicle would not normally pass. It is intended to contain or redirect an errant vehicle of a particular size range, at a given speed and angle of impact.
Barrier System[b]	A system which provides a physical limitation through which an errant vehicle would not normally penetrate or vault over. It is intended to contain or redirect an errant design vehicle of a particular size range, at a given speed and angle of impact.
Barrier Transition	A method by which a change in longitudinal barrier type provides continuous protection to adjacent traffic.
Barrier Warrant	A criterion that identifies a potential need for a traffic barrier.
Bifurcation Point[b]	The point or area at which a roadway divides into two branches or parts.
Bike Lane	A lane intended for the exclusive use of bicycles, within a roadway used by motorized vehicles.
Bike Path	A bicycle facility physically separated from roadways, where motor vehicle traffic, except maintenance vehicles, is excluded.
Bike Route	Any roadway signed specifically to encourage bicycle use.
Bikeway	A roadway, or part of a roadway, intended for the use of bicycles, either exclusively or shared with other vehicular traffic or pedestrians.
Border	The area adjoining the outer edge of the sidewalk.
Boulevard[a]	A reserve which separates the roadway and sidewalk. It provides some protection to the pedestrian and can accommodate street accessories such as traffic signs the fire hydrants. It is a suitable location for underground utilities and may be used for illumination poles. It also provides an area for snow storage.
Brake Reaction Time[b]	The time that elapses from the instant the driver decides to take remedial action, to the instant that remedial action begins (contacts brake pedal).
Braking Distance	The distance travelled from the instant that braking begins to the instant the vehicle comes to a stop.
Break Point	The outer extremity of the shoulder where the side slope begins.
Breakaway	A design feature that allows a device such as a sign, luminaire or traffic signal support to yield or separate upon impact.
Bridge Railing	A longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.
Broken Back Curve	An arrangement of curves in which a short tangent separates two curves in the same direction.
Building Line	A line prescribing the nearest limits for the erection of buildings in relation to a roadway.

TERM	DEFINITION / DESCRIPTION
Bulbing	A widened portion of the median or outer separation, usually at an intersection.
Bullnose[b]	Location where edge of highway and edge of ramp meet each other. Bullnose may include or exclude curb and gutter.
Bus Only lane (BOL), busway, or transitway[b]	Managed lane dedicated primarily to buses
Channelization	The separation and direction of traffic movements and pedestrians into defined paths at an at-grade intersection through the use of geometric features, pavement markings and traffic control devices.
Choker (Curb Bulb)	A narrowing of a roadway, either at an intersection or mid-block, in order to reduce the width of the roadway surface.
Clear Zone[a]	The unobstructed, traversable area provided beyond the edge of the through travelled way available for use by errant vehicles. The clear zone includes shoulders, bike lanes, and auxiliary lanes, except those auxiliary lanes that function like through lanes. The clear zone also includes recoverable slopes, and non-recoverable slopes with a clear run-out area. The selected clear zone width is dependent upon traffic volumes and design speed, and roadside geometry.
Climbing Lane	A lane added on the right side of a roadway on an upgrade intended for use by trucks and other slow vehicles to discourage these vehicle types from using the through lanes.
Collector Lanes[a]	Those lanes of an express/collector system separated from express lanes by an outer separation.
Collector Road	A road on which traffic movement and access have similar importance.
Collision	An event in which travel by a vehicle results in the vehicle being in an inappropriate location, or in an appropriate location at an inappropriate time, culminating in unwanted contact with a fixed object, vehicle, other roadway user or other obstacle.
Collision-Free	Circumstances under which a collision will never occur, i.e. "absolute" safety.
Commercial Motor Vehicle (CMV)[b]	A motor vehicle having a permanently attached truck or delivery body, including fire apparatus, busses, and truck tractors and trailers (combination units) used for hauling purposes on the highways, and requiring a Commercial Vehicle Operating Registration (CVOR).
Construction Work Zone	An area occupied for three or more days for the purpose of constructing, reconstructing, rehabilitating, or performing preventive maintenance. A construction work zone extends from the first Temporary Traffic Control (TTC) device to the last TTC device
Continuous Right-Turn Auxiliary Lane	A right-turn lane that is continuous for a significant distance serving a number of driveways.
Controlled Access	The condition where the opportunity for access to a roadway is controlled by public authority.
Corner Clearance	The distance between the near curb of a street intersection and the near edge of a driveway throat or public lane.

TERM	DEFINITION / DESCRIPTION
Crash	Not used. (See "Collision")
Crash Cushion[a]	An energy attenuating system which provides a physical limitation through which an errant vehicle would not normally penetrate. It is intended to contain or redirect or stop an errant design vehicle of a particular size range, at a given speed and angle of impact.
Crest Vertical Curve	A vertical curve having a convex shape in profile viewed from above.
Criterion	A value, determined either by mathematical relationships or by experience, that represents the degree of excellence required for a particular application, acknowledged as appropriate for that application where prevailing conditions are normal and typical, recognizing that in atypical circumstances some variation may be appropriate. It may be regarded as a basis for assessing existing designs and formulating opinion on their quality, but is not treated as a rigid value to which there is any obligation for designs to conform.
Cross Fall (Cross Slope)	The average grade between edges of a cross section element.
Crossover[b]	Any portion of a roadway distinctly indicated for pedestrian crossing by signs on the highway and lines or other markings on the surface of the roadway as prescribed by the regulations and the Highway Traffic Act, with associated signs Ra-4, Ra-4t, Ra-5L, Ra-5R, Ra-10, and Ra-11.
Cross Section	The transverse profile of a road.
Cross Street	A street of lower classification that crosses a roadway of higher classification, either at grade or passing over or beneath.
Crosswalk[a]	Any portion of a roadway, at an intersection or elsewhere, distinctly indicated for pedestrian crossing by appropriate pavement markings and/or signs, or by the projections of the lateral lines of the sidewalk on opposite sides of the road.
Crown	The highest break point of the surface of a roadway in cross section.
Cul-De-Sac	A road opens at one end only.
Curb	A structure with a vertical or sloping face along the edge of a lane or shoulder strengthening or protecting the edge or clearly defining the edge.
Curb Drop	The transition length required to decrease the curb height to accommodate a driveway or sidewalk ramp.
Curb and Gutter[b]	Curb and gutter is placed adjacent to an outside lane or shoulder and is intended to control and conduct storm-water and also provides delineation for traffic. In some instances, curb is introduced without a gutter.
Curb Return	The curved section of curb used at intersections or driveways in joining straight sections of curb.
Curve to Spiral (CS)	The point of alignment change from circular curve to spiral curve, in the direction of stationing.
Curvilinear Alignment	An alignment in which the majority of its length is circular and spiral curve.
Cut[b]	A roadway located below natural ground elevation is said to be in cut.
Cut Side Slope[b]	Where the roadway is in cut, the slope between the road-way and drainage channel is referred to as a cut side slope.
Deceleration Lane[a]	An auxiliary lane to enable a vehicle exiting from a roadway to reduce speed after it has left the through traffic lanes as applied at channelized

TERM	DEFINITION / DESCRIPTION
	intersections, or as speed-change lane at interchanges.
Decision Sight Distance	The distance required for a driver to detect an information source or hazard which is difficult to perceive in a roadway environment that might be visually cluttered, recognize the hazard or its potential threat, select appropriate action, and complete the manoeuvre safety and efficiently.
Deflection Angle	The angle between a line and the projection of the preceding line.
Departure Taper	The taper required beyond a flared intersection to laterally shift the through lanes to the left, back to a normal alignment or cross section.
Design Consistency	An indication of the quality of design offered by a roadway.
Design Controls[b]	Factors outside the designer's discretion that may affect the design process and designed solution. Examples include traffic volumes, vehicle size and weight, atmospheric conditions, driver, and other human characteristics.
Design Criteria[b]	Characteristics by which the sufficiency of a design feature may be assessed
Design Exception	A "Design Exception" is a documented decision to design elements of highway for criteria that do not meet minimum values or ranges established in the highway standards, policies or specifications.
Design Features[b]	Geometric and dimensional characteristics of the roadway and roadside, including horizontal and vertical alignment and cross sectional elements.
Design Speed[a]	A speed selected for purposes of design and correlation of the geometric features of a road and is a measure of the quality of design offered by the road. It is the highest continuous speed at which individual vehicles can travel with safety on a road when weather conditions are favourable and traffic density is so low that the safe speed is determined by the geometric features of the road.
Design Hour Volume (DHV)	An hourly traffic volume selected for use in geometric design.
Desirable Value[b]	The value at the top of a range of values in a design standard, or the discreet value when a range is not given in a design standard.
Desired Speed	The Operating Speed that drivers will adopt on the less constrained alignment elements of a reasonably uniform section of road (e.g., the longer straights and large radius horizontal curves) when other vehicles or users do not affect their speed choice.
Development Roadway	A roadway whose primary purpose is to provide access to undeveloped areas.
Detour[b]	A construction work zone mitigation strategy wherein traffic in one or both directions is rerouted onto an existing highway to avoid a construction work zone. Detoured vehicles may travel on permanent roads only or on a combination of permanent and temporary roads. This strategy compensates for the removal of permanent travel lanes from service
Development Roadway	A roadway whose primary purpose is to provide access to undeveloped areas.

TERM	DEFINITION / DESCRIPTION
Diversion	A construction work zone mitigation strategy wherein traffic in one or both directions on a designated route is carried by a temporary roadway around a work area and reconnected with the permanent infrastructure of the designated route. This strategy compensates for the removal of permanent travel lanes from service.
Double Left-Turn Lanes	A pair of adjacent lanes intended for the exclusive use of vehicles about to turn left. Interchangeable with dual left-turn lane.
Drainage Channel[a]	A drainage channel is placed adjacent to an outside lane or shoulder and is intended to control and conduct storm-water runoff. A shallow drainage channel is sometimes referred to as a swale.
Earth Roadway	A roadway that has a driving surface consisting of subgrade material.
Easement	A right acquired by public authority to use or control property for a designated purpose.
Effective Wheelbase (EWB)	The distance from the centroid of the front axle group to the centroid of the rearmost axle group, which significantly influences the turning envelope. For two-axle vehicles, total and effective wheelbase are the same.
Emergency Turnouts	Segments of wider-than-typical shoulder. May be provided as disabled vehicle refuge at regular intervals or where conditions permit on roadways (perhaps temporary) where it is not practical to provide a continuous full-width shoulder. May also be referred to as intermittent shoulders.
End Treatment	The method by which the end of a barrier facing on-coming traffic is treated to minimize its hazard.
Energy Attenuator	See “Crash Cushion”.
Entrance	The general area where turning roadway traffic enters the main roadway.
Entrance Terminal	The part of an entrance comprised of acceleration lanes or speed change lanes, including the ramp proper up to the ramp controlling curve.
Exit	The general area where turning roadway traffic departs from the main roadway.
Exit Terminal	The part of an exit comprised of deceleration lanes or speed change lanes, including the ramp proper up to the ramp controlling curve.
Express Lanes[a]	Managed lane that restricts access or a ML that employs electronic tolling in a freeway right-of-way with or without access restrictions. Express lanes can be located within tolled or non-tolled facilities and may be operated as reversible flow or bi-directional facilities to best meet peak demands.
Express-Collector System	A freeway in which the through or express lanes are physically separated from the collector lanes.
Express toll lane (ETL) [b]	ETL is a limited access managed lane employing electronic tolling that charges users’ toll, and they do not exempt high occupancy vehicles.
Expressway	A divided arterial road for through traffic with full or partial control of access and with some interchanges.
False Grading	The practice of distorting the profile of a roadway, relative to the top of curb, so as to avoid flat grades in order to effect drainage.
Fill[b]	A roadway located above the natural ground elevation is said to be in fill.

TERM	DEFINITION / DESCRIPTION
Fill Side Slope[b]	Where the roadway is in fill, the slope between the roadway and the natural ground is referred to as the fill side slope or sometimes the fill slope.
Flare	The variable offset distance of a barrier to place it further from the travelled way.
Flexible Barrier	A form of the longitudinal barrier that is intended to redirect an errant vehicle by rail tension, usually through a system of cables installed in tension.
Four-Lane Divided Highway[b]	A highway consisting of four (4) through lanes total, with two (2) through lanes in each direction which are separated by an unpaved area or physical barrier, including but not limited to a curbed island.
Four-Lane Road[b]	A road that provides two through lanes of traffic in each direction.
Frangible	Readily or easily broken upon impact.
Freeway[a] (Multi-Lane Freeway)	A multi-lane, divided highway with more than four (4) through lanes total (two (2) through lanes in each direction) with a continuous dividing median. This highway is a fully controlled access road limited to through traffic, with access through interchanges and a posted speed of greater than 90km/h.
Friction Factor	The coefficient of friction between tire and roadway, measured either longitudinally or laterally.
Front Overhang (FOH)	The distance from the front bumper of a vehicle to the centroid of its front axle group.
Frontage Roadway	A road contiguous to a through road so designed as to intercept, collect and distribute traffic desiring to cross, enter or leave the through road and to furnish access to property.
Full Road Closure	A construction work zone mitigation strategy wherein traffic operations are removed or suspended in either one or two directions on a segment of roadway or ramp
Geometric Design	The selection of the visible dimensions of the elements of a road.
Gore Area[a]	Area between edge of highway, edge of ramp and bullnose.
Grade Separation	Vertical separation of two intersecting roadways or a roadway and a railway.
Gradient (Grade)[a]	The rate of rise or fall with respect to the horizontal distance; usually expressed as a percentage.
Gravel Road	A road that has a driving surface consisting of granular material.
Guiderail (Guardrail)	See “Barrier”.
Guidelines	Outlines of acceptable practice.
Gutter	A paved shallow waterway provided for carrying surface drainage.
Gutter Line	The bottom of the curb face where it meets the concrete gutter, or the paved surface where a gutter is not employed.
Gutter Lip	The edge of a concrete gutter opposite the curb where it meets the paved roadway.
Hazard	Any obstacle or other feature such as an embankment, or a body of water of depth greater than 1 m which, without protection, is likely to cause significant injury to the occupants of a vehicle encountering it.
Heuristic	An aid to design based on experience – a “rule of thumb”.

TERM	DEFINITION / DESCRIPTION
High-Occupancy-Toll (HOT) Lane, also referred to as Value-Priced lanes) [b]	HOV lane that is electronically tolled for single- or lower occupancy vehicles and free to higher-occupancy vehicles
High-Occupancy-Vehicle (HOV) Lane[a]	Managed lane restricted primarily to high-occupancy vehicles (no tolling applied)
High-speed Highway	A road or highway on which traffic operates with an 85th-percentile free-flow speed of 80 km/h or greater
Highway	Synonymous with roadway but generally limited to higher-speed roadways in rural areas.
Horizontal Alignment[a]	The configuration of a road or as seen in plan, consisting of tangents, lengths of circular curve, and lengths of spiral or transition curves.
Horizontal Curve	A circular curve to plan to provide for change of direction.
Independent Alignment	A divided highway in which each roadway is designed independently both in horizontal and vertical alignment, to take advantage of topographical features.
Inside Lane	The left lane in one direction of a roadway with two or more lanes in that direction also referred to as an inner lane.
Interchange	A grade-separated intersection with one or more turning roadways for travel between the through roads.
Intermittent Closure	A construction work zone mitigation strategy wherein all traffic in one or both directions is stopped for a relatively short period to allow for construction operations.
Intersection (At-Grade)	The general area where two or more roads join or cross, within which are included the roadway and roadside facilities for traffic movements.
Intersection Approach	That part of an intersection leg used by traffic approaching the intersection.
Intersection Sight Distance (ISD)	The sight distance to left and right available to a driver intending to execute a maneuver onto a through roadway from an intersecting roadway.
Island	A defined area between traffic lanes for control of vehicle movements or for pedestrian refuge and the location of traffic control devices.
King's Highway[b]	An administrative classification referring to all Provincial numbered lower than 500, and including the Queen Elizabeth Way (Q.E.W.)
Lane (Traffic Lane)	A part of the travelled way intended for the movement of a single line of vehicles.
Lane Closure	A construction work zone mitigation strategy wherein one or more travel lanes and any adjacent shoulders are closed to traffic. As defined here, this term is not limited to closing one lane of a multilane highway. Lane closures are inherent to median crossovers.
Lane Constriction	A construction work zone mitigation strategy wherein the width of one or more travel lanes is reduced. The number of travel lanes may be retained (possibly through median or shoulder use) or reduced.
Left-Turn Lane	A lane added on the approach to an intersection for the exclusive use of left-turning vehicles.
Length of Need	Total length of a longitudinal barrier needed to shield an area of concern.

TERM	DEFINITION / DESCRIPTION
Local Roadway	A road intended to provide access to development only.
Long Combination Vehicle (LCV)	A combination of a tractor and trailer(s) used for special purposes, with an overall length greater than 25 m. Examples are 'triples' and 'turnpike doubles'.
Longitudinal Barrier[a]	A barrier placed adjacent to a roadway, intended to contain a vehicle leaving the normal travel path, by re-directing it.
Low Volume Roadway[a]	A road with average daily traffic of 200 vehicles per day of less, and whose service functions are oriented toward rural road systems, roads to or within isolated communities, recreation roads and resource development roads.
LRT	Light rail transit.
Mainline	The principal route.
Median[a]	The area that laterally separates traffic lanes carrying traffic in opposite directions. A median is described as flush, raised or depressed, referring to the general elevation of the median in relation to the adjacent edges of traffic lanes. The terms wide and narrow are often used to distinguish different types of median. A wide median generally refers to depressed medians sufficiently wide to drain the base and subbase into a median drainage channel. Flush and raised medians are usually narrow medians.
Median Barrier[a]	A longitudinal barrier placed in the median to prevent a vehicle from crossing the median and encountering oncoming traffic or to protect a vehicle form a fixed object in the median.
Median Crossover	A construction work zone mitigation strategy used on freeways and multilane divided highways to establish two-way traffic. In this strategy: • The number of lanes in both directions is reduced; • At both ends, traffic in one direction is routed across the median to the opposite-direction roadway on a temporary roadway constructed for that purpose; and • Two-way traffic is maintained on one roadway while the opposite direction roadway is closed. This strategy involves the inherent use of median crossovers, and this strategy may be employed in combination with use of shoulder.
Merging-End	The physical end of an entrance terminal between the outer travel lane and the ramp, beyond which traffic merges. Also known as the painted wedge.
Minimum Passing Sight Distance	The least visible distance required by a driver in order to make a passing manoeuvre safely, based on a given set of circumstances.
Minimum Stopping Sight Distance	The least stopping sight distance required by a driver to come to a stop under prevailing vehicle, pavement and climatic conditions.
Minimum Turning Radius (TR)	The radius of the path of the outside of the outer front wheel for the minimum radius turning condition. In former TAC Design Guides, this dimension was used to denote the minimum design turning radius.
Minimum Value[b]	The value at the bottom of a range of values in a design standard.
Multi-Lane Roads[b]	Roads having more than two through lanes of traffic in each direction. In the Traffic and Capacity chapter Multilane refers to four lanes or more.
Multi-Use Path (MUP)	A path with multiple users of different types (e.g., pedestrians, bicycles, and similar user types); a MUP may be shared (all users share the same pathway

TERM	DEFINITION / DESCRIPTION
	space, with or without a marked centre line) or may be separated (i.e., the pathway is separated into parallel travelled ways, e.g. one exclusively for pedestrians and one exclusively for bicycles).
Multi-Use Trail (MUT)	See “Multi-Use Path”.
Narrow Median[b]	A median without an unpaved area or physical barrier between opposing through lanes.
Noise Berm/Barrier	A physical barrier, consisting of compacted earth in a trapezoidal shape, used as a means of minimizing the transmission of traffic sounds.
Normal Crown	A cross section in which adjacent surfaces slope in opposite directions from the centre line or a lane edge to effect drainage to the sides.
Nominal Safety	Nominal safety is a consideration of whether the highway design elements meet minimum design criteria. For example, if design features such as lane width, shoulder width, lateral clearance, etc. meet the minimum values or ranges, the highway proposed design is considered to have nominal safety.
Obstacle[a]	Any fixed object which is likely to cause significant injury to occupants of a vehicle encountering it. Or Any non-breakaway and non-traversable feature within the roadside environment greater than 100mm in height that can increase the potential for personal injury and vehicle damage when struck by an errant vehicle leaving the roadway.
Offset Mid-Block Crossing	A pedestrian crossing on a divided roadway in which the alignment of the crossing is staggered at the median.
One-lane One-way Road	A road with one lane that carries one-directional traffic.
One-lane Two-way Road	A road that provides sufficient roadway width for the safe passing of opposing vehicles.
Operating Speed	The 85th percentile speed of vehicles at a time when traffic volumes are low and drivers are free to choose the speed at which they travel.
Outer Separation[a]	A reserve on freeways (including shoulders) between lanes carrying traffic in the same direction.
Outside Lane	The right lane in one direction on a roadway with two or more lanes in that direction (also referred to as an outer lane).
Overall Length	The distance between the front bumper of the power vehicle and the rear bumper on the rear unit of a vehicle or trailer combination. It equals the sum of its effective wheelbases, front overhand and rear overhang.
Overpass (vehicle)	A grade separation in which the subject road passes over an intersecting road or railway.
Painted Wedge	See “Merging-End”.
Parameter	A quantity that is a variable in the general case and is constant in the specific case under consideration. (Radius of circular curve is an example, in which radius varies from one curve to another but for one particular circular curve is the same at any point on the curve~~.~~).

TERM	DEFINITION / DESCRIPTION
Parclo	An abbreviation for the PARtial CLOverleaf interchange, a grade separation having loop ramps in fewer than all four quadrants.
Parking Lane	A supplementary lane intended for parking.
Passing Lane	A supplementary lane intended for passing.
Passing Opportunity	The distance ahead required to be visible to a driver to initiate a passing maneuver safely.
Passing Sight Distance	The distance ahead visible to the driver available to complete a passing maneuver.
Perception Time[b]	The time that elapses from the instant that a driver observes an object for which it is necessary to stop, until the instant that he decides to take remedial action.
Platform Intersection	An intersection in which the area common to the two roadways is at the same elevation as the top of curb or sidewalk.
Policy	Principle, course of action, or strategy adopted by government, government agency or technical organization that reflects prevailing community values, intended to provide direction and guidance in the selection of technical and non-technical criteria for general application, and specific dimensions in the planning and design process. Policy necessarily incorporates some element of political or other non-technical community viewpoints.
Posted Speed	A speed limitation introduced for reason of safety, economy, traffic control and government regulatory policy aimed at encouraging drivers to travel at an appropriate speed for surrounding conditions.
Public Lane (Alley)	A narrow minor street, usually without sidewalks, located at the rear of lots for vehicle access to garages or other parking spaces and which also serves as a utility right of way.
Raised Crosswalk	A crosswalk on a curbed street whose elevation is the same as the top of curb or sidewalk.
Ramp	A turning roadway to permit the movement of traffic from one highway to another.
Reaction Time	The time that elapses from the instant a visual stimulus is perceived by a driver to the instant the driver takes remedial action.
Rear Overhang (ROH)	The distance from the rear bumper of a vehicle to the centroid of its rearmost axle group.
Recovery Area	Generally synonymous with clear zone.
Retrofit	The reconstruction of an existing roadway with geometric improvements.
Reverse Crown	A typical surface cross section in which adjacent surfaces slope in the same direction at the normal crown.
Reverse Curve	Two curves, curving in opposite directions from a common point.
Right-Of-Way (ROW)	The area of land acquired for or devoted to the provision of a road.
Right-Turn Lane	A lane added on the approach to an intersection for the exclusive use of right-turning vehicles.
Right-Turn Taper	The taper from the edge of the through lane to the beginning of a right-turning roadway at an intersection, where an auxiliary lane is not used.

TERM	DEFINITION / DESCRIPTION
Rigid Barrier	A form of longitudinal barrier that is intended to redirect an errant vehicle with minimum deflection in the barrier system and usually consist of a continuous concrete mass.
Road	The entire right-of-way comprising a common or public thoroughfare, including a highway, street, bridge and any other structure incidental thereto.
Roadside	The area adjoining the outer edge of the roadway.
Roadside Barrier	A longitudinal barrier used to shield roadside obstacles or non-traversable terrain features. It may occasionally be used to protect pedestrians from vehicle traffic.
Roadside Environment[b]	The portion of the ROW beyond the roadway, including medians, not designed for vehicular use. The roadside environment may include a variety of surfaces and slopes, fixed Obstacles (such as signs, poles, bridges piers, abutments, culverts, ditches, sideslopes, backslopes, barrier systems, crash cushions, etc) and natural features (such as water bodies, trees and other vegetation, boulders and rock outcrops, etc).
Roadway	That part of the road that is improved, designed or ordinarily used for the passage of vehicular traffic, inclusive of the shoulder.
Roadway Hump	A speed control device in which the roadway surface is raised over a length of about 3.5 to 4.0 m to a maximum height of 80 mm.
Roundabout	A channelized intersection in which traffic moves counterclockwise around a centre island of sufficient size to induce weaving movements in place of direct crossings. It is sometimes referred to as a rotary or traffic circle.
Rounding[a]	Width between edge of shoulder and cut or fill slope.
Rumble Strips	Indentations in the surface of a paved shoulder that provide an audible or tactile warning to a driver that the vehicle has left the travelled lane.
Runout Length[ab]	The distance parallel to the roadway, measured from the object to the point of vehicle encroachment. This distance varies with design speed and traffic volume.
Rural Area	An area characterized by low density development on large parcels.
Safety Zone[a]	An area officially established within a roadway for the exclusive use of pedestrians, protected or so indicated as to be plainly visible.
Sag Vertical Curve	A vertical curve having a concave shape in profile viewed from above.
Secondary Highway[b]	An administrative classification referring to all 500, 600, and 700-Series Provincial Highways.
Semi-rigid Barrier[a]	A form of longitudinal barrier that is intended to direct an errant vehicle by a system of steel beam action to adjacent posts.
Service Road	Same as frontage road but not necessarily contiguous with the through road.
Severity Index[b]	A number from zero to ten used to categorize the potential severity of an encroachment or impact by an errant vehicle for a range of design speeds over a variety of surfaces and slopes, fixed objects and natural features within the roadside environment. The number is used for evaluating alternative safety treatments.

TERM	DEFINITION / DESCRIPTION
Shared Street	A street designed to be shared by pedestrians, cyclists, and slow-moving motorists, with no physical separation of modes and typically an emphasis on use as a livable public space.
Shielding	The introduction of a barrier or crash cushion between a vehicle and an obstacle or area of concern to reduce the severity of impacts of errant vehicles.
Shoulder[a]	Areas of pavement, gravel or hard surface placed adjacent to through or auxiliary lanes. They are intended for emergency stopping and travel by emergency vehicles only. They also provide structural support for the pavement.
Shoulder Closure	A construction work zone mitigation strategy wherein a shoulder is closed to traffic
Shy-Line Offset	A distance beyond which a roadside object will not be perceived by a driver to be a threat, to the extent of changing lane position or speed.
Sidewalk	A travelled way intended for pedestrian use, following an alignment generally parallel to that of the adjacent roadway.
Sight Distance	From any given point, the unobstructed distance a driver can see, usually along the roadway ahead.
Sight Distance at Intersection[b]	See “Intersection Sight Distance”.
Sight Triangle	The triangle formed by the line of sight and the two sight distances of drivers, cyclists or pedestrians approaching an intersection on two intersecting streets.
Simple Open Throat Intersection[a]	A simple or un-channelized intersection where additional area of pavement may be provided for turning of large vehicles.
Slot Left-Turn Lane	On a divided roadway, a left-turn lane which is angled and situated entirely within a wide median to accommodate a divisional island between the left-turn lane and the adjacent through lane.
Speed Hump	See “Roadway Hump”.
Speed Change Lane	A deceleration or acceleration lane.
Spiral Parameter (A)[a]	“A” designates the sharpness of the spiral. It is a measure of the flatness of the spiral, the larger the parameter, the flatter the spiral.
Spiral to Curve (SC)	The point of change form spiral curve to circular curve, in the direction of stationing.
Spiral to Tangent (ST)	The point of change from spiral curve to tangent, in the direction of stationing.
Spline	A flexible drafting tool used to draw curved lines of varying radii.
Staged Freeway[b]	A freeway (typically rural) that is planned to be a multi-lane dived freeway that is built using staged construction. In the plans for each stage of development, provisions should be made to adapt each stage to the next or the ultimate stage (completion). The transition should be

TERM	DEFINITION / DESCRIPTION
	made with minimum waste of the exiting plant and minimum interference to traffic. Typically, this might include treatments such as interim at-grade intersections in lieu of interchanges.
Standard	A value for a specific design feature, which practice or theory has shown to be appropriate for a specific set of circumstances, where no unusual constraints influence the design.
Steering Angle	The angle between the longitudinal axis of the vehicle and the direction of the steering wheels, limited by the dimensions of parts of the steering mechanism.
Stop Block[b]	Pavement marking to indicate where vehicles are required to stop for a traffic control device.
Stopping Distance	The distance travelled by a vehicle from the instant the driver decides to stop, to coming to a stop.
Stopping Sight Distance	The distance between a vehicle and an object, for which the driver decides to stop, to the instant the vehicle begins to come into view.
Street	Synonymous with road, but generally limited to lower speed roads in urban areas.
Street Furniture	Practical and decorative features introduced into the streetscaping, intended to enhance the comfort, convenience and aesthetic quality of the roadway environment.
Streetscaping	The practice of applying aesthetic treatments to the street and its facilities, intended to enhance the quality of the roadway environment.
Suburban Area	An area characterized by larger scale developments. Building coverage and development density can vary, but typically are less than in Urban Areas.
Substantive Safety	Substantive Safety is the expected or estimated long-term average, safety performance of a roadway. The concept of substantive encompasses methods for estimating the following expected quantitative measures: • Collision Frequency • Collision types • Collision severity
Summer Average Daily Traffic (SADT)[b]	The average 24-hour, two-way traffic for the period July 1st to August 31st including weekends.
Superelevation	The gradient measured at right angles to the centre line across the roadway on a curve, from the inside to the outside edge.
Superelevation Runoff	The transition between a typical section of normal crown and a fully superelevated section. (See also Tangent Runout.)
Surfaced Roadway	A roadway in which the travelled lanes have been hard surfaced, usually by some form of bituminous or concrete surface.
Swale	A shallow drainage channel.
Tangent Runout	The length of road needed to accomplish the change in cross slope from a normal cross-section to a section with the adverse crown removed.

TERM	DEFINITION / DESCRIPTION
Tangent to spiral (TS)	The point of alignment change from tangent to spiral curve, in the direction of stationing.
Taper	Where an auxiliary lane is being developed or terminated, the straight-line transition from the edge of the through lane to the beginning of the full width auxiliary left- or right-turn lane.
Target Speed	The speed at which the designer intends for traffic to operate.
Temporary Roadway	A roadway constructed to carry highway traffic exclusively during construction. Temporary roadways are used in conjunction with diversion and median crossover work zone strategies and may be used with a detour work zone mitigation strategy.
Temporary Traffic Control	A construction work zone mitigation strategy wherein devices and measures are used to facilitate road users through work zones
Terminal[b]	A crashworthy end treatment or crashworthy anchor used at the end of a barrier system.
Tertiary Highway[b]	An administrative classification referring to all 800-Series Provincial Highways.
Throat Length	The provision of sufficient unobstructed on-site driveway length to prevent stopped vehicles from blocking the path of entering vehicles or vehicles travelling along the circulation roadways on site.
Through Lane	A lane intended for through traffic movement.
Toll Lane (Toll Road)[a]	A road open to traffic only upon payment of a direct toll or fee; sometimes called tollway, throughway, turnpike or auto-route. (may not be a managed lane if travel benefits are not assured)
Total Wheelbase (TWB)	The centre-to centre distance from the front axle to the rearmost axle of a tractor-trailer combination. (The nomenclature used for design vehicles is based on total wheelbase, for example "WB-19" refers to a tractor-semitrailer having a total wheelbase of approximately 19 m.)
Traffic barrier/Barrier[b]	Traffic barriers are placed adjacent to a roadway to protect traffic from hazardous objects either fixed or moving (other traffic). Barriers placed in a median are referred to as median barriers and may be placed in flush. Raised or depressed medians.
Traffic Management Plan[b]	A strategy to manage the work zone impacts of a project. Each TMP will include a Traffic Staging Plan
Traffic Staging Plan[b]	Drawings showing the plan, profile, cross section, signage and pavement markings of a specific stage of the work zone
Trail	A beaten or maintained path or track often for a specified type of traffic (e.g. ski trail).
Transit Lane	A lane intended primarily for public transit vehicles.
Transition	A method by which a change in longitudinal barrier type provides continuous protection to errant vehicles.
Transition (spiral) curve	A curve whose radius continuously changes.

TERM	DEFINITION / DESCRIPTION
Travelled Way[a]	That part of a roadway intended for vehicular travel. This includes through lanes, turn lanes, and other auxiliary lanes. This does not include shoulders or ancillary space. It may have a variety of surfaces but is most commonly hard surfaced with asphalt or concrete or gravel surfaced.
Truck Escape Ramp (TER)	A ramp provided on the right side of a long downhill section of roadway to allow vehicles (usually trucks) to escape in the event of brake failure.
Turning Roadway	A separate roadway or ramp to accommodate turning traffic at the intersection or interchange of two roads.
Turnout	A widened section of roadway provided for passing of vehicles travelling in opposite directions on a one-lane roadway, or in the same direction on a two-lane roadway.
Two-Lane Road	A road that provides for one lane of through traffic in each direction.
Two-Way Left-Turn Lane (TWLTL)	The middle lane on a two-way undivided street intended for the exclusive use of vehicles about to turn left from either direction into property accesses.
Underpass	A grade separation in which the subject roadway passes under a roadway or railway.
Use of Shoulder[b]	A construction work zone mitigation strategy involving the use of a right-side or median shoulder as all or part of a temporary traffic lane. This strategy compensates for the removal of permanent travel lanes from service. Employing this strategy may require constructing or upgrading shoulder pavement structures to adequately support traffic loads.
Urban Area	An area characterized by extensive development and building coverage.
Vertical Alignment[a]	The configuration of a road or roadway as seen in longitudinal section, consisting of tangents and parabolic curves.
Vertical Curvature (K)	The horizontal distance along a parabolic curve required to effect a one percent change in gradient.
Vertical Curve[a]	A parabolic curve on the longitudinal profile or in a vertical plane of a road to provide for change of gradient.
Warrant[a]	A criterion that identifies a potential need or the justification for an addition to the highway such as traffic signals, traffic barrier, truck climbing lanes, passing lanes, left turn lanes etc.
Waterbody[b]	Any natural or constructed body of water.
Watercourse[b]	Any stream, river, or channel in which flow of water occurs either continuously or intermittently.
Weaving	The condition in which vehicles move obliquely from one lane to another, and cross the paths of other vehicles moving in the same direction.
Weaving Lane	A lane added to provide additional capacity and operational improvement in sections of roadway experiencing weaving.
Weaving Section	A section of roadway between an entrance and an exit, such that the frequency of lane changing exceeds that for open highway condition.
Wide Median[b]	A median on a divided roadway and/or freeway consisting of an unpaved area or physical barrier between opposing through lanes.
Work Zone Design	A selected speed used to determine specific work zone geometric

TERM	DEFINITION / DESCRIPTION
Speed[b]	design features.

NOTES:

a These definitions are modified from the Glossary of TAC Geometric Design Guide for Canadian Roads - June 2017.

b These definitions are in addition to ~~in~~ the Glossary of TAC Geometric Design Guide for Canadian Roads - June 2017.