Ontario

ROADSIDE SAFETY MANUAL

MINISTRY OF TRANSPORTATION
QUALITY & STANDARDS DIVISION

ISBN # 0-7778-0859-5

CONTINUING RECORD OF REVISIONS MADE

to the

ROADSIDE SAFETY MANUAL

This sheet should be retained permanently in this page sequence in the Manual.
All revised material should be inserted as soon as received and the relevant entries made by hand in the spaces provided to show who incorporated the Revision and the date this was done. If this practice is followed faithfully it will be a simple matter to tell whether or not this copy of the Manual is up to date since all future Revisions will be dated.

Revision		Entered by	Date
No.	Date		

To all users of this publication:

The information contained herein has been carefully compiled and is believed to be accurate at the date of publication. Freedom from error, however, cannot be guaranteed.

Enquiries regarding the purchase and distribution of this manual should be directed to:

Publications Ontario

By telephone: 1-800-668-9938
By fax: (613) 566-2234
TTY: 1-800-268-7095
Online: www.publications.gov.on.ca

Enquiries regarding amendments, suggestions, or comments should be directed to the **Ministry of Transportation** at (905) 704-2065

ISBN 0-7778-0859-5

Roadside Safety Manual

ISBN 0-7778-0859-5

FOREWORD

The first edition of The MTO Roadside Safety Manual is a publication of the Ministry of Transportation Ontario, for use in the Province of Ontario. It is a standard and policy document for the provincial highway system, and may be used as a guide by other jurisdictions in Ontario.

The manual incorporates the Ministry's current standards, policies, practices, and expertise in the areas of roadside safety. It provides a documented set of policies, guidelines, and procedures for use principally, by Ministry planners and designers, but also by Ministry construction and operations staff. Use of the manual will assist in providing cost effective safety treatment and uniform application of roadside safety.

Additional and more detailed safety related information may be obtained from various other manuals as detailed elsewhere in Chapter 1 and the related sections within this manual.

The information presented in this manual was carefully researched. However no warranty, expressed or implied, is made on the accuracy of the contents or their extraction from referenced publications; nor shall the fact of distribution constitute responsibility by the Ministry of Transportation of Ontario, or any researchers or contributors for omissions, errors or possible misrepresentation that may result from use or interpretation of the material herein contained. The information contained herein is to be carefully used, however good engineering judgement may still be required on a site specific basis.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY

AADT	Average annual daily traffic
Barricade	A device which provides a visual indicator of a hazardous location or the desired path a motorist should take. It is not intended to contain or redirect an errant vehicle.
Barrier	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.
Breakaway	A design feature which allows a device such as a sign, luminaire, or traffic signal support to yield or separate upon impact. The release mechanism may be a slip plane, plastic hinges, fracture elements, or combination of these.
Bridge Railing	A longitudinal barrier whose primary function is to prevent an errant vehicle from going over the side of the bridge structure.
Clearance	Lateral distance from edge of travelled way to a roadside object or feature.
Clear Zone	The total roadside border area, starting at the edge of the travelled way, available for safe use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a non-recoverable slope, and/or a clear run-out area. The desired width is dependent upon traffic volumes and speed, and on the roadside geometry.
Cost-Effective	An item or action taken which is economical in terms of tangible benefits produced by money spent.
Crash Cushion	An impact attenuating device which brings the vehicle to a safe stop or by redirecting, preventing an errant vehicle from impacting fixed object hazards by gradually decelerating the vehicle away from the hazard.
Crash Tests	Vehicular impact tests by which the structural and safety performance of road-side barriers and other highway appurtenances may be determined. Three evaluation criteria are considered, namely (1) structural adequacy, (2) impact severity, and (3) vehicular post-impact trajectory.
Crashworthy	A feature that has been proven acceptable for use under specified conditions, either through crash testing or in-service performance.
Design Speed	The speed selected and used for correlation of the physical features of a highway that influence vehicle operation. It is the maximum safe speed that can be maintained over a specified section of highway when conditions are so favourable that the design features of the highway govern.
Drainage Features	Roadside items whose primary purpose is to provide adequate roadway drainage such as curbs, culverts, ditches, and drop inlets.
End Treatment	The design modification of a roadside or median barrier at the end of the installation.
Experimental Barrier	A barrier that has performed satisfactorily in full-scale crash tests and that promises, but has not yet demonstrated, satisfactory in-service performance.

Flare	The variable offset distance of a barrier to locate it further from the travelled way.
Frangible	A structure designed to readily break upon impact.
Gating	Characteristic of an end treatment or crash cushion, which allows a vehicle impacting the nose to pass through the device.
Glare Screen	A device used to shield a driver's eye from the headlights of oncoming vehicles.
Guide Rail	See "Barrier".
Hinge	The weakened section of a sign post designed to allow the post to rotate upward when impacted by a vehicle.
Impact Angle	For a longitudinal barrier, the angle between a tangent to the face of the barrier and a tangent to the vehicle's path at impact. For a crash cushion, the angle between the axis of symmetry of the crash cushion and a tangent to the vehicle's path at impact.
Impact Attenuator	See Crash Cushion.
Length of Need	The total length of a longitudinal barrier needed to shield a hazard.
Level of Performance	The degree to which a longitudinal barrier including bridge railing, is designed for containment and redirection of different types of vehicles.
Longitudinal Barrier	A barrier whose primary function is to prevent penetration and safely redirect an errant vehicle away from a roadside or median hazard.
Median	The portion of a divided highway separating the travelled ways for traffic going in opposite directions.
Median Barrier	A longitudinal barrier used to prevent an errant vehicle from crossing the highway median.
Non-recoverable slope	This type of slope is considered traversable but errant vehicles on these slopes will continue on to the bottom, with little chance for recovery. Embankment slopes between 4:1 and 3:1 may be considered traversable but non-recoverable if they are smooth and free of fixed object hazards.
Offset	The distance between the travelled way and a roadside barrier or other obstacle.
Operating Speed	The speed below which 85 % of drivers are operating vehicles on a section of highway under low traffic densities and good weather. This speed may be higher or lower than posted or legislated speed limits or nominal design speeds where alignment, surface, roadside development, or other features affect vehicle operations.
Operational Barrier	A barrier that has performed satisfactorily in full-scale crash tests and has demonstrated satisfactory in-service performance.
Performance Level	See Level of Performance.
Pocketing	Undesirable characteristic which will allow a degree of penetration resulting in sudden deceleration.
Recoverable Slope	A slope on which a motorist may, to a greater or lesser extent, retain or regain control of a vehicle. Slopes 4:1 or flatter, are generally considered recoverable.
Recovery Area	Generally synonymous with clear zone.

Roadside	The area between the outside shoulder edge and the right-of-way limits.
Roadside Barrier	A longitudinal barrier used to shield roadside obstacles or non-traversable terrain features. It may occasionally be used to protect pedestrians or roadside facilities from vehicle traffic.
Roadway	The portion of a highway, including shoulders, designated for vehicular use.
Rounding	The introduction of a smooth transition between two transverse slopes to minimize the abrupt slope change, and to allow a vehicle to traverse such slopes without bottoming out or vaulting.
Shielding	The introduction of a barrier or crash cushion, between the vehicle and an obstacle or area of concern to reduce the severity of impacts of errant vehicles.
Slip Base	A structural element at or near the bottom of a post or pole which will allow release of the post from its base upon impact, but which is still capable of resisting wind loads.
Slope	The relative steepness of the terrain expressed as a ratio or percent change. Slopes may be categorized as positive (backslopes) or negative (foreslopes), and as parallel or cross slopes in relation to the direction of traffic.
Temporary Barrier	Temporary barriers are used to prevent vehicular access into construction or maintenance work zones and to redirect impacting vehicles to minimize damage to the vehicles and injury to the occupants, while providing worker protection.
Traffic Barrier	A device used to prevent vehicles from striking a more severe obstacle or feature located on the roadside or in the median, or to prevent crossover median accidents. As defined in this manual, there are four classes of traffic barriers, roadside barriers, median barriers, bridge railings, and crash cushions.
Transition	Defines an area where two barrier systems that are adjacent one another, either overlap in protection or are physically attached to each other. The transition should produce a gradual stiffening of the approach system so vehicular pocketing, snagging, or penetration at the connection can be avoided.
Travelled Way	The portion of the roadway designed for the movement of vehicles, excluding shoulders the auxillary lanes.
Traversable Slope	A slope from which a motorist will be unlikely to steer back to the roadway but may be able to slow and stop or reach the bottom of the slope safely. Slopes between 4:1 and 3:1 generally fall into this category.
Design Vehicle	A motorized unit for use in transporting passengers or freight, ranging from an 800 kg automobile to a 40 tonne van-type tractor-trailer. It is representative of its class or vehicle group.
Warrants	The criteria by which the need for a safety treatment or improvement can be determined.

DETAILED TABLE OF CONTENTS

1.1 MANUAL OVERVIEW

1.1.1 PURPOSE

This manual replaces the "Design Manual for Traffic Barriers, Energy Attenuators, Light Poles", issued in May 1983, and PHY directives B-012, B-209, B-221, B-236, C-31, C-107, C-151, and Highway Engineering Division Memorandum ED-77-44, 78-9, DD 75-05. Circular 72-21 and Quality and Standards Directives B-10 and B11.

The principal purpose of the manual is to give designers the tools to produce safe, cost-effective designs for dealing with roadside hazards. It is a compilation of the most recent methods and policies that apply to locating and selecting highway traffic barriers (including guide rails, end treatments, and energy attenuators) for highways under the Ministry's jurisdiction. The material has been selected from a comprehensive literature review, a state-of-the-art survey including crash test results from both the United States and overseas, and advice from various offices within and outside of the Ministry. The Manual of Geometric Design Standards for Canadian Roads (1986) published by the Roads and Transportation Association of Canada, and the American Association of State Highway and Transportation Officials' Roadside Design Guide (1988), were used extensively in the preparation of this manual.

This manual is intended to be a universal guide. For Ministry uses, however, whenever the text is intended to state policy, the text is clearly identified under a heading POLICY or WARRANT and is in capitals. Deviations from these sections must be justified and documented, and approval obtained from the Design Criteria Committee prior to completing detail design. By contrast, the recommendations or guidelines contained in the manual, **typically in bold face** may be modified to fit local conditions.

In the design of any highway, a judicious arrangement and balancing of geometric features should eliminate or minimize the need for traffic barriers as much as possible. In addition, barrier systems

must be placed in an environment where they are likely to perform most effectively.
Since it is impossible to cover every roadside situation, this manual, attempts through discussion of both barrier warrants and barrier performance characteristics, to give design staff a reasonable understanding of highway traffic barriers and safety in general, to allow them to make informed decisions.

This manual is issued primarily for the direction and guidance of Ministry of Transportation personnel involved in the design of Ontario provincial highways. The principles contained in this manual apply equally to Ministry construction and maintenance personnel, as well as to staff of municipal jurisdictions. The information concerning maintenance that is included in this manual is intended to supplement more detailed information contained in the Maintenance Manual, and thus this manual does not contain maintenance procedures.

Ministry staff must be aware that the performance of guide rails, end treatments and energy attenuators depends on correct installation. Any deviation from the proper installation methods or modification of the hardware may result in unsatisfactory performance.

A good understanding of the functions and operating characteristics of traffic barriers will help construction and maintenance staff assess site modifications or repairs to traffic barrier systems. If there is doubt as to the proper modifications or repair, staff should consult the Highway Planning and Design Development Section of the Surveys and Design Office, or the Regional Planning and Design Office.

1.1.2 CONTENT

The content and layout of the Design Manual for Traffic Barriers, Energy Attenuators, Light Poles have been revised and updated substantially. Areas that have received particular attention in this manual include end treatments of guide rails, recently developed energy attenuation systems, and warrants and policies that have been developed recently. The manual also discusses cost/benefit analysis and life cycle costs of design alternatives.

Chapter 1, INTRODUCTION, gives a general overview of the manual, and discusses in general terms roadside safety, the clear roadside concept and desirable barrier characteristics.

The main body of the manual is contained in chapters 2 through 6.

Chapter 2, POLICY, WARRANTS, AND DESIGN GUIDELINES, presents Ministry policy with respect to a clear roadside concept, Ministry retrofit policy, warrants for embankments, medians, high performance barriers, and policies and guidelines for the treatment of various types of conditions and safety hazards.

Chapter 3, BARRIER SELECTION, DESIGN AND CONSTRUCTION, discusses the major factors that the designer should consider when selecting an appropriate protection system, including site conditions, barrier deflections, performance expectations, costs, and maintenance considerations, as well as calculation of the barrier length.

CHAPTERS 4, and 5, BARRIER SYSTEMS AND CHARACTERISTICS, and END TREATMENTS AND CRASH CUSHIONS, respectively discuss the various characteristics of approved Ministry safety systems. This includes a description of the system, how the system is intended to perform, considerations for design and installation, and a brief description of the maintenance requirements which may be expected.

Chapter 6, UTILITIES describes the existing policy on light poles and luminaries, which is essentially the same as the information contained in the previous manual. Information concerning High Mast Lighting and other general information are also included. For the most recent information on these subjects designers should contact the Electrical Section of the MTO Traffic Management and Engineering Office.

THIS MANUAL SHOULD BE READ IN CONJUNCTION WITH THE:

Ontario Provincial Standard Drawings (OPSD) - Road Barriers

Ontario Provincial Standard Specifications (OPSS), Volume 1 and 2

MTOD Drawings listed in Chapter H of the CDED Manual

The Geometric Design Standards for Ontario Highways Manual

The Manual of Uniform Traffic Control Devices (MUTCD).

The Ontario Highway Bridge Design Code

Sign Support Manual

Drainage, Sanitary Sewers and Watermains Volume 1

The MTC Drainage Manuals, Volume 1, 2, and 3

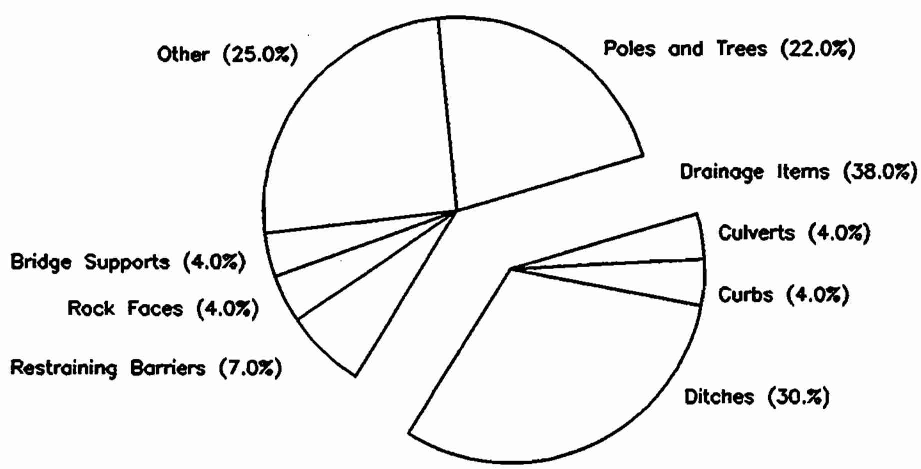
Maintenance Manual Volume 1

Electrical Engineering Manual for Pole selection criteria

1.2 BACKGROUND INFORMATION

1.2.1 ROADSIDE SAFETY

Motor vehicle accidents inflict a tremendous toll on contemporary Canadian society. Although the number of fatalities in Ontario has declined to approximately 1100 per year over the last decade, the overall accident rate has remained relatively constant at about 1.6 accidents per one million kilometres travelled. In 1986, which was representative of the past 10 years, 314, or approximately 33% of the fatal accidents that occurred, were single motor vehicle collisions. In all of these cases the vehicle left the roadway and either overturned or collided with a fixed object. These objects and associated fatalities include:



The design or continued presence of above objects or features adjacent to provincial highways is usually under the direct control of Ministry of Transportation personnel, with the exception of utilities which may have existing agreements regarding the location of their facilities and equipment.

While every effort must be made to keep the motorist on the roadway, this goal can never be fully realized. The highway designer must therefore ensure the roadside environment is structured to minimize the incidence and severity of accidents. The treatment of roadside hazards has usually been considered in the following order of preference:

1. Remove the hazard.

2. Relocate the hazard outside the clear zone.

3. Minimize the hazard by making it traversable or, in the case of sign supports and posts, by using breakaway devices.

4. Shield the hazard with barriers or crash cushions.

5. In the absence of other options, improve awareness of the hazard through delineation or other warning devices.

6. Reduce the posted speed.

If a roadside obstacle represents a potential hazard, the most desirable treatment is to remove or relocate the obstacle, provided that other considerations such as cost and environmental impact make its removal possible. Alternatively, accident severity may be reduced by other means, such as the use of breakaway supports. Traffic may also be protected from the obstacle by a barrier. Removal is preferable to protection with a barrier, since the barrier itself is also a potential hazard, as shown by the above data. Reduction of the posted speed is the least desirable option, and should only become a measure of last resort, and if operational problems are evident, and it is expected that the operating speed will also be lowered.

Vehicles striking barriers and energy attenuators can result in occupant injury and/or vehicle damage. It is, therefore, preferable to eliminate the need for the barrier or attenuator by either removing the obstacle, or reducing the severity of the hazard. In the case of an embankment, this means flattening the side slope to an acceptable degree. A fixed object can either be relocated outside the clear zone, or rendered less dangerous by a breakaway device. In making these choices, the cost-effectiveness of the options must be considered.

Traffic barriers are intended primarily to reduce the severity of injuries to occupants from collision with hazards or other vehicles. Once a barrier comes into use, the accident is already in progress. The purpose of a barrier is therefore not to prevent an accident, but rather to minimize the accident's severity, and to protect occupants of other vehicles on the road.

Median barriers are installed to prevent vehicles crossing the median and striking oncoming traffic, and to protect traffic from colliding with fixed objects in the median, such as light poles and bridge piers. Reduction of cross-median travel may also be accomplished by building a wider median.

Longitudinal barriers are intended to deflect the errant vehicle away from the hazard in a controlled manner, with acceptable deceleration, low exit angle, and minimum injury to the occupants, or damage to the vehicle.

Standard traffic barriers are primarily intended to offer protection to the occupants of passenger cars, and are of limited value for larger vehicles such as trucks and buses. High-performance barrier systems have been designed to be of significant benefit to these larger vehicles, and are discussed in chapter 2, Section 2.10.

BARRIER WARRANTS

A barrier warrant is an empirical expression which combines the degree of need, in terms of the accident severity of a single accident, with the frequency of errant vehicle accidents, and average cost.

Barrier warrants have been derived for the following general situations:

a) roadside terrain which cannot be traversed safely because of natural or man-made obstacles;

b) steep embankment fills;

c) medians on higher volume divided highways where traffic is exposed to oncoming vehicles; and

d) medians on facilities with a high volume of commercial vehicles.

The material contained in this manual provides an elementary explanation of the to factors affecting the design of a safe roadside and, as far as possible, presents rational methods that can be readily applied in the design office. However, where specific criteria are stated or implied, they are given as the minimum standards to be applied in Ontario. There will be cases where these standards should be exceeded, sometimes substantially, to provide optimum safety. The information contained herein must not be considered as a substitute for sound engineering judgement in the treatment of hazardous obstacles.

Even properly designed and constructed longitudinal barriers may not protect errant vehicles and their occupants completely. After their installation, the severity of accidents generally decreases, but with added installations the frequency of minor accidents may also increase.

For the above reason, and where economically feasible, the designer should make every effort to design without guide rail. This can be done by clearing the roadside of obstacles, flattening embankment slopes, or introducing greater median separation when applicable.

Where barriers are required, they should be placed as close to the hazard as the deflection of the barrier allows, to maximize the clear offset from the edge of the travelled way.

The above applies only if the area between the roadway and the guide rail is fully traversable.

Refer to chapter 3.0 section 3.4.2 for maximum slopes that guide rails may be installed on.

1.2.2 DESIRABLE BARRIER QUALITIES

Traffic barriers consisting of longitudinal barriers and/or energy attenuation devices are used where errant vehicles leaving the travelled roadway would be exposed to a hazard that when struck, may cause excessive bodily harm or death to the vehicle's occupant. The criteria to be satisfied in crash testing procedures require:

1) a longitudinal barrier to restrain a selected vehicle that is representative of a sufficiently large range of the vehicle population. The barrier must also assure that a vehicle of specific weight (1800 to 2000 kg design vehicle for standard barriers, and up to 36,000 kg design vehicle for high performance barriers) and dimension, striking the barrier with a specific velocity and approach angle (100 km/h and 10 to 25 degrees) will not climb over, break through, or wedge under the installation. The vehicle must be redirected with tolerable deceleration along a small exit angle back towards the travelled portion of the roadway, and

2) Longitudinal barrier or energy attenuator that is impacted by a selected vehicle along its length to either redirect or stop the vehicle in such a manner that passengers restrained by seat belts can survive, preferably uninjured.

Furthermore, while in service:

1) Longitudinal barrier or energy attenuator should redirect or stop the errant vehicle in such a manner that the vehicle does not become a hazard to following or adjacent traffic. Ideally the vehicle should remain close to the barrier installation, and not be directed back into the traffic stream.

2) During impact,the barrier or attenuation system must function so that the occupants of the errant vehicle and other traffic are not likely to be endangered by vehicle or barrier elements that could intrude into the passenger compartment, or become projectiles.

3) In general, longitudinal barriers should only be used where the result of striking an obstacle or leaving the roadway would be more severe than the consequences of striking the barrier system.

4) The impacting vehicle must not snag on the system, causing excessive deceleration of the vehicle or occupants, and an unpredictable trajectory when leaving the system.

5) The barrier or energy attenuator must not cause the impacting vehicle to roll over or become airborne.

Design vehicles, test matrices, and performance evaluation criteria adopted by the Ministry are described in detail in the National Cooperative Highway Research Program Report 230, "Recommended Procedures For The Safety Performance Evaluation of Highway Appurtenances", March 1981.

All barrier systems described in this manual have been tested at speeds of 100 km/h. Until other appropriate service levels are determined and systems developed and tested for these new speed levels, the barrier systems described in this manual are to be used without alteration.

1.2.3 CLEAR ROADSIDE CONCEPT

Since the 1960's it has been recognized that some motorists, regardless of the improvements made, will run off the roadway, and that serious accidents and injuries can be reduced if a traversable recovery area is provided. This clear zone should be free of obstacles, such as unyielding landscaping, rigid sign supports and light poles, non traversable drainage structures and steep slopes.

Several studies have been carried out into the behavioral patterns of errant vehicles, where the drivers have lost control and the vehicle has left the roadway. The vehicle behaviour depends largely on the nature of the roadside, speed, the circumstances that caused the loss of control and the characteristics of the vehicle. On traversable roadside terrain, the driver may regain control after a portion of the energy of the vehicle has been dissipated.

To determine the critical area of the roadside which must be clear of hazards or where protection is required, three parameters are used. These are:

(1) the angle at which a vehicle leaves the travelled surface;

(2) the distance the vehicle travels along the roadway; and

(3) the offset that the vehicle penetrates the roadside.

Based on numerous accident studies, empirical curves of this data have been produced for operating speeds of approximately 100 km/h. These curves are shown in Figures 1.2.1, 1.2.2, and 1.2.3.

For relatively flat and level roadsides, the clear zone concept is simple to apply. As indicated on these figures, 80 percent of errant vehicles leaving the roadway at speeds of approximately 100 km/h have a departure angle of less than 17 degrees, length of roadside travel is less than 135 m, and the final distance from edge of pavement is less than 9 m.

These values are derived from broadly based data and the curves may not apply at any specific location due to local characteristics such as design speed, horizontal curvature, cross section geometry and traffic volumes. The Ministry has established clear zone distances to be used on provincial highways based on the above data and design speed. Refer to Chapter 2, Section 2.2. Refer also to Chapter 1, Section 1.4, Risk Acceptance.

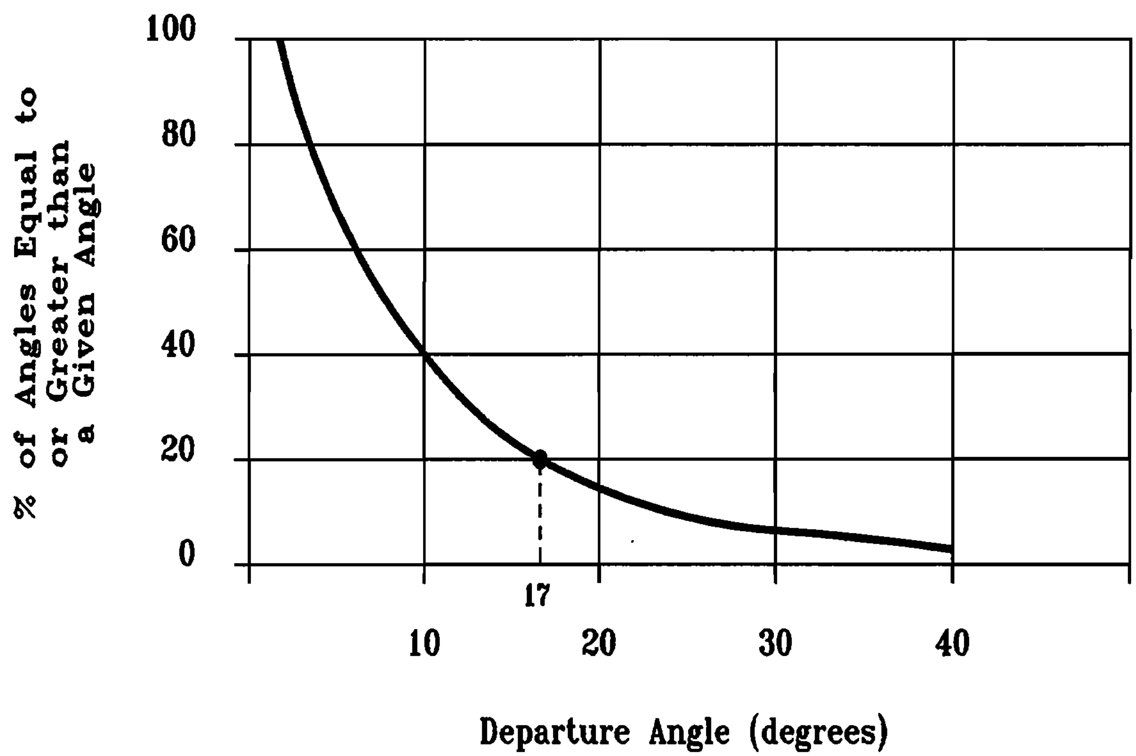


Figure 1.2.1 Distribution of Angles for Vehicles Departing the Roadway

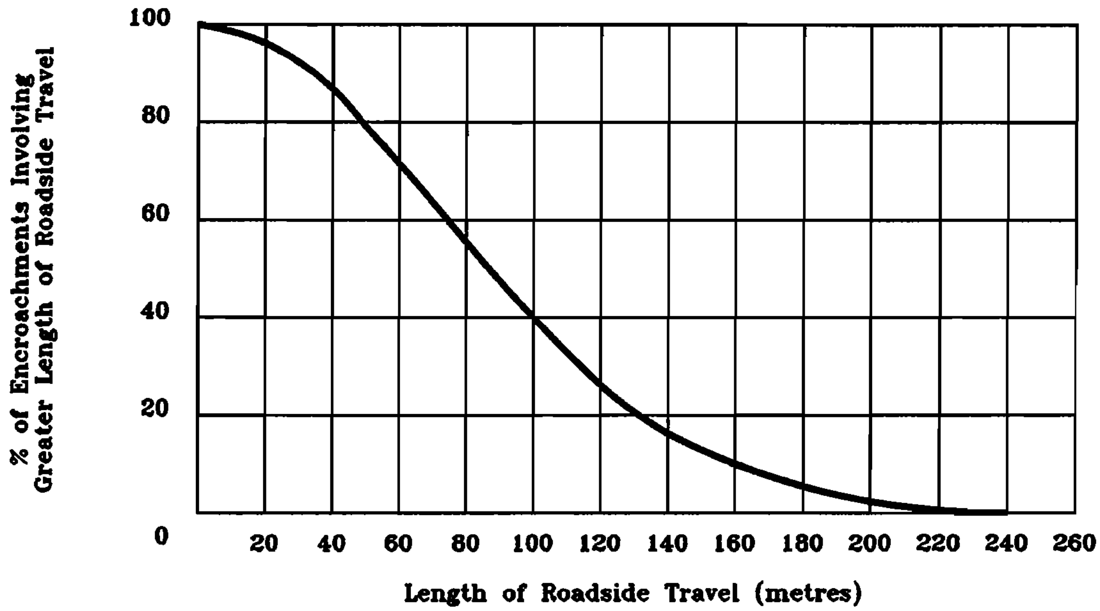


Figure 1.2.2 Length of Roadside Travel for Errant Vehicles

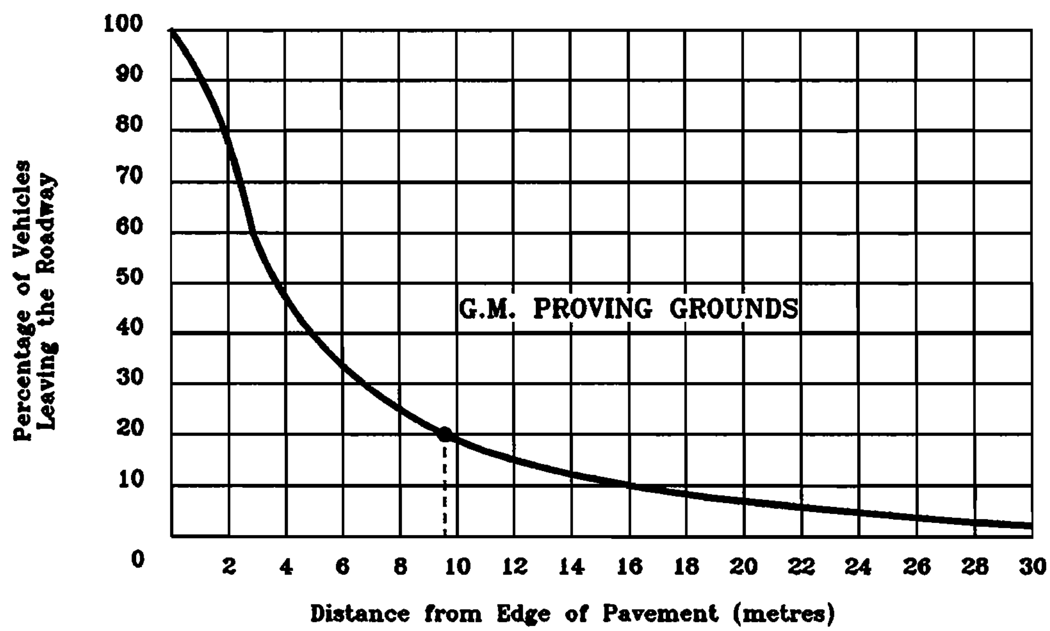


Figure 1.2.3 Depth of Penetration from Edge of Pavement for Errant Vehicles

1.3 SAFETY CONSCIOUS DESIGN

GENERAL

Significant improvements in safety are not automatic by-products of resurfacing or re-construction projects. Safety must be systematically designed into each project. The designer must deliberately seek opportunities in each project to apply sound safety and traffic engineering principles. Designers of resurfacing or re-construction projects work with existing highways where the design and operational characteristics can be measured and observed, however, these factors are not always used to maximum benefit.

At the beginning of the project the designer should assess existing physical and operational conditions affecting safety by using accident data, site inspections and existing design and traffic characteristics. Special consideration should be given to locations where the consequences of an accident may be severe. These may include schoolyard play areas, or fairgrounds adjacent to the right-of-way.

When determining the project scope, in addition to considering pavement repairs, geometric improvements and guide rail upgrade, other intersection, roadside and traffic control improvements that may enhance safety over and above the improvements specified in Section 2.3 should also be considered. Low cost enhancements to safety may include using surplus material to flatten side slopes or construct berms to protect isolated hazards outside the clear zone, installing bevelled ends on existing culverts, or (in wide medians) piping traverse drainage through the median, and including ditch inlets and fill to make a smooth transition.

The preliminary design report should include all identified safety problems and safety enhancement opportunities, and related design options.

Chapter 2.0, Section 2.3 details the minimum safety requirements the designer must include on all capital projects.

GUIDE RAIL PHILOSOPHY

Where economically feasible the designer should make every effort to design without the use of guide rail. This can be done by clearing the roadside of obstacles, flattening embankment slopes, or introducing greater median separation where practical. Where guide rails are required they should be placed as close to the hazard as the deflection of the barrier allows, to maximize the clear offset from the edge of the travelled way, provided that the area between the travelled way and the face of the guiderail is fully traversable. Refer to Chapter 3, Section 3.4.3, for allowable slopes for installation. **Under no circumstances should the guide rails direct the errant vehicle towards a hazard such as rock cuts, poles, etc.**

1.4 RISK ACCEPTANCE

The alternative to removing, replacing or shielding hazards is to accept some risk. The risk acceptance alternate is usually the best choice when the cost of other acceptable alternates out weigh the potential benefits of reduced accident severity. Although other criteria might indicate a need for corrective action, if funds for safety improvements are limited, it will be a prudent alternative to accept the risk at low priority locations so available funds can be concentrated where they will achieve the greatest safety return. This alternative increases in acceptability when there is a long record showing little or no run-off-the-road impacts, and where there is a low possibility of future accidents. On the other hand, risk acceptance may be unacceptable in the event of a clear accident pattern or if future accidents appear likely.

The suitability of the risk acceptance alternative is a function of accident history and the possibility of future accidents. The accident history should consider multiple years of run-off-the-road impacts with the hazard in question. Unfortunately, we do not have a fully satisfactory basis to evaluate the possibility of future accidents. In the final analysis, this judgement must be made on the basis of personal knowledge and professional assessment of the hazard, roadway, site and traffic conditions.

If it is decided not to follow policy but to accept risk, approval of the Design Criteria Committee is required. Reasons for risk acceptance must be documented in the project file.

DETAILED TABLE OF CONTENTS

2.4 END TREATMENTS AND TRANSITIONS

2.5 EMBANKMENTS

2.6 CUTS

2.9 INTERSECTIONS

2.10 MEDIAN PROTECTION

2.1 CHAPTER OVERVIEW

This chapter provides the designer with Ministry policies, warrants and guidelines to assist in the selection and application of traffic barriers.

Where warrants and policies are stated, the designer must not deviate without approval from the Design Criteria Committee. On occasion, and in the interest of expediency as an interim measure, a directive may be issued to state a new or modified policy. These directives will be cancelled at each revision of this manual.

This chapter covers the policy and guidelines for barriers use, together with a set of warrants which are broad enough in scope to allow for most applications, taking into account the diversity of terrain and geometric and traffic conditions encountered.

The guidelines are only recommendations, and should not be regarded as a substitute for sound engineering judgement in the treatment or removal of hazardous obstacles. Where standard drawings are referred to, they are to be considered as minimum requirements that may at times have to be exceeded to obtain a better design, in terms of safety and sustainable development.

Ministry staff must understand that the performance of all guide rails, end treatments and crash cushions depends on correct installation. Any deviations from the proper installations and modifications to the hardware may result in unsatisfactory performance.

The custodial office of this manual is to be consulted regarding design problems that require deviations from standards, to ensure safety and consistency of design applications.

2.2 CLEAR ZONE POLICY

OVERVIEW

A significant number of serious accidents and injuries can be reduced if a clear zone is provided. This clear zone must be traversable, and should be free of obstacles such as unyielding landscaping, sign supports and light poles, non traversable ditches or drainage structures, and steep slopes. Vehicles striking barriers and energy attenuators can cause some occupant injury and/or vehicle damage. It is, therefore preferable to eliminate the need for these by either removing the hazard or reducing its severity.

For background information on the clear zone concept, refer to Chapter 1, Section 1.2.3. Refer also to Chapter 1, Section 1.4 for Risk Acceptance.

DEFINITION

Clear zone width is defined as the distance from the edge of the travelled portion of the roadway to the face of an unprotected hazard. This clear zone must be traversable, allowing errant vehicles to recover or come to a safe stop. Any hazards which remain within this offset must be either removed or shielded. The clear zone relative to the traffic in the opposite direction is typically measured from the centreline.

At locations where traversable nonrecoverable embankments are within the clear zone, and do not require protection according to the Embankment Warrant Guide, Chapter 2, Section 2.5.1, the clear zone definition is modified and is measured from the toe of the non-recoverable slope. Since it is expected that vehicles leaving the roadway may be in the process of braking a design speed 20 km less than that of the roadway may be used to calculate the clear zone offset from the toe of slope. Refer to example 3, Chapter 2, Section 2.5.

JUDGEMENT

The designer should use judgement when applying the clear zone offsets. Where the cross section or slope of the terrain tends to channel errant vehicles towards a hazard outside the clear zone, or for critical isolated hazards, such as permanent bodies of water, bridge piers, rock outcrops, etc., just beyond the clear zone, where the consequences of a collision may be extremely severe, consideration should be given to providing protection for the motorist. The designer should be aware that the clear offsets provide degree of protection for approximately 80% of errant vehicles. While this may be a cost-effective measure across the entire system, in isolated, high risk locations, the clear zone offsets should be exceeded, especially when there is little or no additional cost involved in doing so. The key consideration is driver expectancy of a hazard and the risk exposure. Conversely, if isolated objects, say trees, are found to be just within the zone, while other trees in the immediate vicinity are outside the clear zone, removal of the tree inside the hazard zone will not significantly reduce the risk to motorists. Protection or removal may not be necessary in this case. See Figure 2.2.2.

2.2.1 CLEAR ZONE WIDTH - TANGENT

This section specifies the clear zone offsets to be used on Provincial Highways on tangent sections.

POLICY

ANY HAZARDS WITHIN THE CLEAR ZONE WHICH CANNOT BE REMOVED OR MADE FORGIVING MUST BE PROTECTED BY AN APPROVED BARRIER SYSTEM OR CRASH CUSHION. ON LOWER VOLUME ROADS THE CLEAR ZONE MAY BE REDUCED TO THE OFFSETS SHOWN IN PART B TABLE 2.2.1, SUBJECT TO AN OPERATIONAL REVIEW AS OUTLINED BELOW.

The Clear Zone offsets to be applied on tangent road sections are shown in Table 2.2.1.
For curved roadways, refer to Section 2.2.2. For risk acceptance refer to Chapter 1, Section 1.4.

APPLICATION

The clear zone offsets apply to permanent hazards. It should not be used as justification for providing protection from opposing traffic such as locations with narrow medians with low volumes or nested ramps. The median barrier warrant guide, Figure 2.10, applies in the former situation.

OPERATIONAL REVIEW

General

It is normal practise for a traffic analyst to review the following material and compare the application, use and resultant performance against other similar locations that have been established as acceptable and hence represent benchmarks to which all remaining installations will be compared. This may be done from a municipal perspective, a regional view, or from a province wide overview. It is the responsibility of the traffic analyst to identify any operational concerns along with the determined cause and relay these concerns to the designer.

Table 2.2.1
Clear Zone Widths - Tangent Road Sections

*Design Speed km/h	**Clear Zone Width (m)				
	A		B		
	AADT ≥ 6000		AADT ≥ 1500	AADT ≥ 750	AADT < 750
120	10		8	7	6
110	9		7	6	5
100	7		6	5	4
90	6		5	4	4
80	5		4	4	4
70	4		3	3	3
60 or less	3		3	3	3
60 or less with barrier curb	0.5		0.5	0.5	0.5

** For point of measurement see "definition"
* For explanation of Design Speed refer to the Geometric Design Manual

Refer to Section 2.2.3 for application of the Clear Zone in urban areas.

On any project where these offsets cannot be cost-effectively accommodated and protection is not provided, a statement in the design criteria will indicate this fact. Approval of the Design Criteria Committee will be required. Justification for reduced offsets will be retained in the project file.

Procedure

Operational analysis typically includes a review of:

- Motor Vehicle Accident Reports with the focus on determining causal factors including the influence of roadway geometrics. Typically reviews will focus on the following information:
  - injury/occupant ratios
  - injury severity (i.e. fatals, major injuries, minor, etc.)
  - injuries/collision
  - vehicle damage severity
  - sequence of events
  - driver action
  - location on/off roadway
  - fixed object involvement/offset from roadway
  - environmental considerations
  - visibility conditions
  - vehicle condition

- Volume information initially to determine flow patterns and future growths/demands. This data is combined with accident data to produce accident rates so that the operation may be compared to benchmarks representing operations elsewhere in the Province. Volume data is used to produce the following information;
  - General characteristics such as AADT
  - Traffic composition
  - Turning movement information

- Geometric information in conjunction with accident data and volume data to assess general highway characteristics. Reviews generally assess the use of standards versus as constructed and attempts to determine the role if any that roadway geometrics may have played in the day to day operation or in the occurrence of accidents. The analyst should review the following geometric concerns;

- vertical and horizontal alignment
- number of through lanes
- existence of auxiliary lanes
- shoulder width and surface condition
- traffic barrier types and location
- median types/widths
- curb and gutter type/location
- sidewalk locations
- structure locations/clearance/capacity for traffic (vehicular and pedestrian)

- Existing traffic control devices in conjunction with accident data, volume data, and knowledge of geometric conditions to determine what role if any that the presence of absence of traffic control devices may have had on the day to day operations or what manner it may have contributed to a motor vehicle accident. The analyst must review the location, position, and functionality of the following devices;
  - traffic signals
  - signing/delineation
  - pavement marking
  - special devices (i.e. railway gates, etc.)

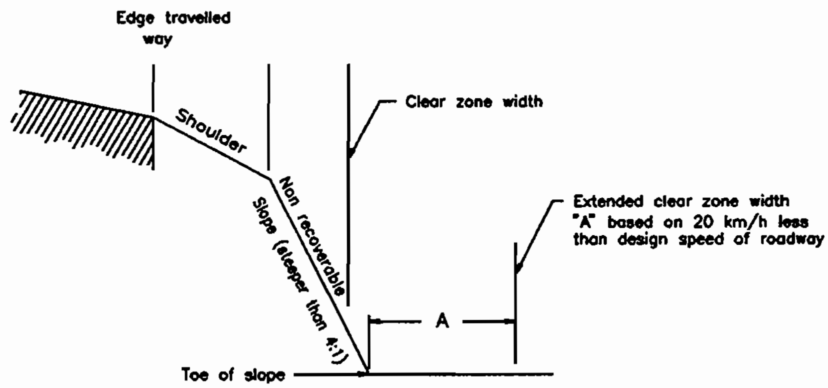


Figure 2.2.1 Extension of Design Clear Zone

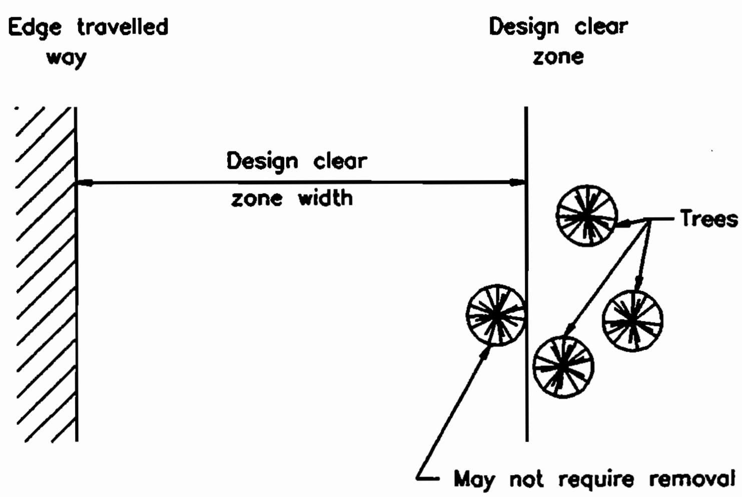


Figure 2.2.2 Decrease in the clear zone to accommodate judgement

2.2.2 CLEAR ZONE WIDTH - CURVE

Vehicles out of control while travelling on a horizontal curve can be expected to travel further away from the roadway due to centrifugal forces on the outside and due to the driver tendency to oversteer on the inside. The tangent clear zone offsets must therefore be increased to compensate for this.

POLICY

CLEAR ZONE WIDTHS ON BOTH THE INSIDE AND OUTSIDE OF HORIZONTAL CURVES MUST BE INCREASED, TO ALLOW FOR THE CENTRIFUGAL FORCE ON THE OUTSIDE, AND THE TENDENCY TO OVER STEER ON THE INSIDE.

Table 2.2.2 Provides curve correction factors for increasing clear zone widths on the inside and outside of curved road sections.

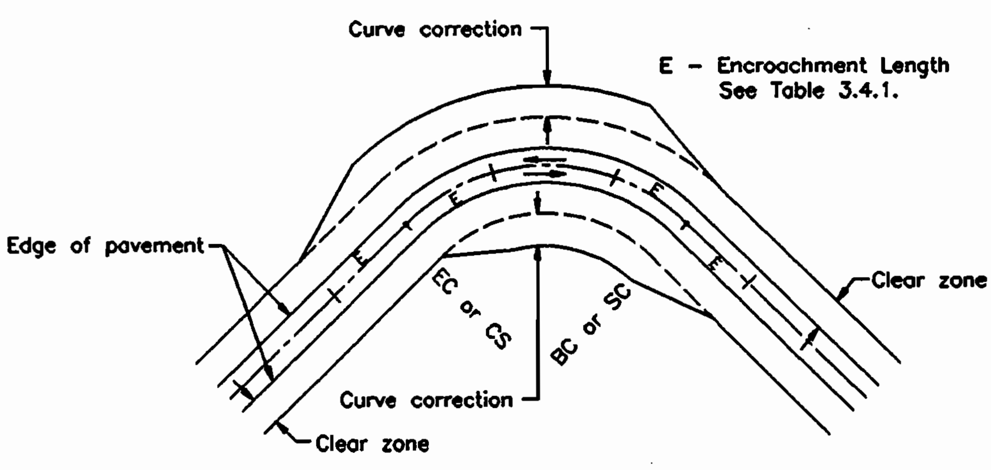


Figure 2.2.3 Clear Zone Extension on Curve

PROCEDURE

Total clear zone widths on the outside and inside of curves are obtained by multiplying the clear zone widths for tangents, (Table 2.2.1) by the appropriate curve correlation factor (provided in Table 2.2.2) and rounding to the nearest 0.5 metre. Exceptions to the clear zone width are to be treated as shown in Section 2.2.1.

Table 2.2.2
Curve Correlation Factors

Radius (m)	Design Speed (km/hr)						
	60	70	80	90	100	110	120
1000	1.00	1.00	1.00	1.00	1.00	1.00	1.00
900	1.07	1.09	1.11	1.15	1.19	1.24	1.31
800	1.08	1.10	1.13	1.17	1.23	1.28	1.34
700	1.09	1.12	1.15	1.20	1.25	1.32	1.43
600	1.10	1.14	1.17	1.23	1.29	1.37	1.46
500	1.11	1.16	1.22	1.27	1.35	1.44	-
400	1.14	1.19	1.27	1.35	1.42	-	-
350	1.17	1.23	1.31	1.39	-	-	-
300	1.20	1.27	1.35	1.46	-	-	-
250	1.22	1.32	1.42	-	-	-	-
220	1.25	1.35	-	-	-	-	-
200	1.29	1.40	-	-	-	-	-
180	1.32	1.45	-	-	-	-	-
150	1.35	-	-	-	-	-	-
120	1.4	-	-	-	-	-	-
100	1.5	-	-	-	-	-	-
50	1.75	-	-	-	-	-	-

2.2.3 CLEAR ZONE - URBAN AREAS

The offsets shown in Table 2.2.1 may not always be practical in urban centres. In these communities, utility poles, fire hydrants, etc. may be located immediately adjacent to the roadway. Removal or relocation may not be possible, and shielding with guide rails may not be practical, due to the number of entrances and crossings.

GUIDELINE

In urban areas where the operating speed is 60 km/h or less, a barrier curb may be used to shield hazards, provided the clear zone offsets cannot be met and removal or relocation is not practical. Also refer to Sections 6.3 to 6.7.

2.3 RETRO FITTING POLICY

2.3.1 CAPITAL CONSTRUCTION PROJECTS

While current safety standard requirements have been addressed in new capital construction projects, they have been less rigidly applied for rehabilitation and reconstruction projects. Changes in standards and warrants over an extended period have resulted in outdated and substandard barrier installations. This section presents ministry policy for rehabilitation and reconstruction projects, which must be followed by the designer.

POLICY

A FORMAL REVIEW OF ROADSIDE SAFETY REQUIREMENTS IS TO BE CARRIED OUT DURING THE DETAILED DESIGN STAGE OF ALL PROVINCIAL HIGHWAY CAPITAL CONTRACTS THAT INCLUDE THE ACTIVITIES LISTED IN TABLE 2.3.2 AS PER PROCEDURES.

GUIDE RAILS, END TREATMENT, ENERGY ATTENUATORS

This review should include a review of the highway inventory, traffic and maintenance input, and a field inspection. A site meeting should be held with the construction, maintenance and traffic offices before detail design completion to ensure that all proposed and existing installations meet Ministry standards. This is in addition to the Regional technical review. Structure barrier walls should be reviewed with the Structural Section.

All existing barrier installations within or adjacent to the project limits, as well as all approach and leaving barrier installations adjacent to structural rehabilitation projects, are to be upgraded to current design standards. The designer must check that existing protection is still warranted. If not, it must be removed. The designer must also check the mounting height and the length of installation, general condition of the barrier, and determine if the latest standards are being used. For allowable tolerances on resurfacing projects refer, to Table 2.3.1

The term "adjacent" as used above includes all barrier installations that terminate at or are transitioned to another barrier type within 150 metres beyond the project limits. At structural rehabilitation projects where existing barriers are continuous for more than 150 m beyond the structure, upgrading is mandatory for only the first 20 m, plus or minus, of barrier adjacent to the structure, including connections to the structure. However, every consideration should be given to doing additional work. If the system is no longer an approved standard, such as single cable guide rail, it must be replaced.

If the barrier, end treatment, or connection is no longer an approved standard, it must be removed, with the following exceptions:

1) The concrete New Jersey Shape which is being replaced by the F shape, is not considered to be substandard, and thus does not require upgrading.

2) Existing standard concrete barrier need not be upgraded to high performance barriers unless the barrier is being removed for other purposes.

3) Butt ended steel beam guide rail connection to structure need not be replaced, provided the connection is sound, and no other work on the structure wall is required. The remainder of the connection, (ie. post spacing) must be brought to standard.

4) The upright leaving end of guide rail on divided highway or a one way ramp need not be turned down or flared back when it can not be struck from the wrong direction. Typically a 25 metres clearance is adequate.

PAVED SHOULDERS

Refer to the Geometric Design Manual for Ontario Highways, Chapter D for paved shoulder policy.

PAVEMENT DROP-OFF

Refer to the Geometric Design Manual for Ontario Highways, Chapter J for paved shoulder policy.

PROCEDURES

Capital projects

For all Provincial Highways Program capital projects covered by this policy:

1) The Design Criteria shall include a statement that traffic barrier requirements will be reviewed, and existing installations upgraded where appropriate, in accordance with current Ministry policy.

2) Condition of the existing guide rail system is to be documented in the work project file prior to the technical review, and any exceptions to the design standards are to be justified, approved and recorded. The following information is to be summarized for each category of hazard and barrier type:

   - general location and total length of new barrier
   - barrier type or Standard Number
   - type of treatment at barrier ends, transitions and structure approaches
   - location and type of energy attenuators, and
   - existing barrier requiring removal or modification to meet design standards.

3) During construction significant deviations from the specified traffic barrier installations shown in the contract documents are not permitted unless approved by the Regional Planning and Design Office in consultation with the Regional Traffic Section. The reasons for the deviations must be documented in the Project Construction Report.

Table 2.3.1
Allowable Deviations From Standard Mounting Heights of Existing Guide Rail Systems on Resurfacing Projects

SYSTEM	Standard Mounting height (mm)	Allowable Deviations (mm)	Permissable Mounting height (mm)
3 or 6 cable	685	+ 25 - 25	710 660
Box Beam	735	+ 25 - 50	760 685
Steel Beam no channel	530	+ 25 - 25	555 505
Steel Beam with channel	610	+ 25 - 105	635 505
Conc Barrier	825	- 75	750

Table 2.3.2
Capital Activities where Review and Upgrading of Existing Traffic Barrier Installations Policy Applies

COMPONENT	CAPITAL ACTIVITIES
Highway Services	° New Construction of - Highways - Intersections - Interchanges ° Widening of existing highways
Road Surface	° Resurfacing & Grading Projects ° Reconstruction of Highways
Structures	° Construction or Reconstruction of: - Bridges - Parapet Walls - Concrete Culverts
Safety Devices	° New Installation & Planned Upgrades of: - Truss/Automated Signs - Illumination - Traffic Barriers

2.3.2 NON-CAPITAL PROJECTS

GUIDELINE

Out-dated and substandard barrier installations on non-capital projects, or situated on sections of roadway not on the construction program may be handled by the District office if serious operational problems or hazards have been identified by the designer, Regional traffic staff or District patrols.

Under normal circumstances such work would be scheduled to coincide with capital construction on the highway section or in the immediate vicinity. Depending on the scope and seriousness of the problem, it could accelerate the programming of work on the section.

This accelerated program may be achieved by taking advantage of funds which are made available from time to time for employment creation and for safety enhancement. Funds may also be available for limited hazard removal programs such as Roadside Safety Improvement Initiative. As a rule of thumb, locations with recurring accidents should be given priority, followed by removal of or protection of rigid objects, prioritized by offset and traffic volume.

2.4 END TREATMENT AND TRANSITION POLICY

POLICY

IT IS MINISTRY POLICY TO USE ONLY DEVICES AND PROCEDURES DOCUMENTED IN THIS MANUAL. OTHER DEVICES, (EVEN THOUGH THEY MAY BE APPROVED BY OTHER JURISDICTIONS), ARE NOT TO BE USED WITHOUT AUTHORIZATION FROM THE SURVEYS AND DESIGN OFFICE.

DESIGN/INSTALLATION GUIDES AVAILABLE FROM THE MANUFACTURER/ DISTRIBUTOR, ARE NOT BE BE USED INSTEAD OR IN CONJUNCTION WITH MINISTRY STANDARDS WITHOUT AUTHORIZATION FROM THE SURVEYS AND DESIGN OFFICE.

The recent crash testing of existing systems, and the development and testing of new systems for the treatment of barrier ends and transitions between different barrier types, have resulted in a new emphasis on safety at guide rail ends, and at transitions from one system to another. This has been reflected in the following policies.

2.4.1 END TREATMENTS

POLICY - APPROACH END TREATMENT

ALL GUIDE RAIL ENDS, ROADSIDE OR MEDIAN, INCLUDING THOSE LOCATED AT BULLNOSE AREAS, LOCATED WITHIN THE CLEAR ZONE AS SHOWN IN TABLES 2.2.1, MUST BE PROTECTED BY AN APPROVED END TREATMENT OR ENERGY ATTENUATION DEVICE.

(Refer to Chapter 5 for approved end treatments.)

POLICY - LEAVING END TREATMENT

ON UNDIVIDED HIGHWAYS, ALL GUIDE RAIL LEAVING END TREATMENTS MUST BE TREATED AS APPROACH ENDS RELATIVE TO THE OPPOSITE TRAFFIC.

ON DIVIDED HIGHWAYS THE LEAVING ENDS OF BARRIER SYSTEMS MUST BE TURNED DOWN OR TAPERED. FLARING IS NOT REQUIRED. This should only be done if the end cannot be struck by any vehicle, otherwise end treatments must be applied. On structures a leaving end system may not be required, unless warranted by the embankment protection warrant guide, or to protect a hazard adjacent to the structure.

PROCEDURE (refer also to Chapter 3, Section 3.5)

Steel Beam

The EXTRUDER or the ECCENTRIC LOADER assembly, is to be used on all shoulder installations of steel beam guide rail, if the ends are within the clear zone. The traditional turned down steel beam treatment must not be used unless the entire turned down portion is located beyond the clear zone given in Chapter 2, Section 2.2, or buried in a cut backslope.

All steel beam guide rail approach ends meeting at bullnose areas, or in front of median hazards within the clear zone, must be protected by an approved energy attenuation device.

Concrete

The primary method of protecting approach ends of concrete barrier within the clear zone shall be the TREND, (See Chapter 5, Section 5.2.3). Where the TREND is not appropriate other approved energy attenuator or end treatment with proper transition shall be used. Installations may only be treated with the flared and turned-down end, as shown on OPSD 918.03, if the entire turned-down portion is located beyond the clear zone offset, as specified in Chapter 2, Section 2.2, Tables 2.2.1 and 2.2.3.

Precast Temporary Concrete Barriers

Refer also to Chapter 2, Section 2.12. All approach end treatments of Temporary Concrete Barrier shall be treated in one of the following three manners:

- connected to an existing permanent barrier by means of a transition rail

- attached to, or shielded by, an approved end treatment or crash cushion, typically the GREAT (Chapter 5, Section 5.2.2), or CAT (Chapter 5, Section 5.2.4) for narrow hazards, and CIAS (Chapter 5, Section 5.3.3) for wider hazards. **Sand-filled, energy-absorbing modules (See Chapter 5, Section 5.3.4) should not be used to shield the approach ends of temporary barriers on facilities posted at 80 km/h or greater. They may be used when other devices cannot be accommodated.**

- installed such that the entire turned down portion of the flared treatment depicted in OPSD 920.02, is located beyond the clear zone offset shown in Table 2.2.1 (Chapter 2, Section 2.2).

Box Beam

All Box Beam end treatments are to be installed with the flared and turned down end as shown on the appropriate standard drawing contained in the OPSD manual. Also (See Chapter 3.5.1).

Cable

All cable end treatments are to be installed turned-down, as shown on the appropriate standard drawing contained in the OPSD manual.

2.4.2 TRANSITIONS

POLICY

TRANSITIONS ARE REQUIRED WHERE SYSTEMS OF DIFFERING DEFLECTION OR STIFFNESS CHARACTERISTICS MEET IN PERMANENT AND TEMPORARY INSTALLATIONS.

The transition is applied so that the end of the more rigid system does not become a hard point, with potential spearing or snagging. The transition must be designed to achieve a smooth transition from one system to the other.

The approved transition types for the various guide rail systems are shown in the OPSD manual. The approved transitions between temporary and permanent guide rail systems and barriers are presently available in MTOD format, and expected to be available as OPSD Drawings at a later date. (Refer also to Chapter 2, Section 2.12.)

CONSIDERATIONS

In shoulder transitions from cable to steel beam, and steel beam to cable guide rail, several alternate methods may be used. The steel beam may be flared 3.06 m, and left upright.
If the flared end cannot be fully accommodated on the roadside embankment, the ECCENTRIC LOADER, flared 1.22 m, should be used. If either of these treatments can not be accommodated, contact the Surveys and Design Office for alternate designs. Any transition treatment used must be designed so that the differences and deflection of the systems are taken into account.

It is critical that a proper transition be employed wherever there is a danger that an approaching vehicle may strike the junction of the two systems. Refer to Chapter 4.0 for additional information on transition treatments of the various systems.

It is not desirable to construct transitions from one system to another on curves or other locations with a higher probability of accidents.

NOTE: The embankment widening required for transition treatments must be included in the design cross-sections, to ensure the widening is not forgotten during the grading operation.

2.5 EMBANKMENTS

2.5.1 EARTH EMBANKMENTS

OVERVIEW

Embankment or fill slopes parallel to the flow of traffic may be defined as recoverable, non-recoverable, or critical.

Recoverable slopes:

Recoverable slopes are defined as earth embankment slopes 4:1 or flatter, and are included in the clear zone offset. Motorists who encroach on recoverable slopes can generally stop their vehicle or slow it enough to return to the roadway safely. Recoverable slopes will not likely require protection. However, this should be verified on a site specific basis. Fixed object hazards such as culvert head walls should not extend above the embankment slope, both within the clear zone, and preferably beyond, if the embankment is otherwise traversable to the bottom.

Non-recoverable slopes:

A non-recoverable slope is defined as one which is traversable, but from which most motorists will be unable to stop or to return to the roadway easily. Vehicles on such slopes typically can be expected to reach the bottom. Embankments between 3:1 and 4:1 may fall into this category if they are smooth and free of fixed surface hazards. Since a high percentage of encroaching vehicles will reach the toe of these slopes, the clear zone cannot logically end on the slope and a clear run out area must be provided at the base. See also Section 2.2.1. Non-recoverable slopes may not require protection, however this should be verified on a site specific basis.

Critical slope:

A critical slope is one on which a vehicle is likely to overturn. Slopes steeper than 3:1, and rock embankments (Section 2.5.2) generally fall into this category. If a slope steeper than 3:1, with a depth of fill greater than 3 m and 2 m on undivided and divided highways respectively, begins closer to the travelled way than the suggested clear zone for that specific roadway, a barrier may be warranted if the slope cannot readily be flattened.

NEED FOR GUIDE RAIL

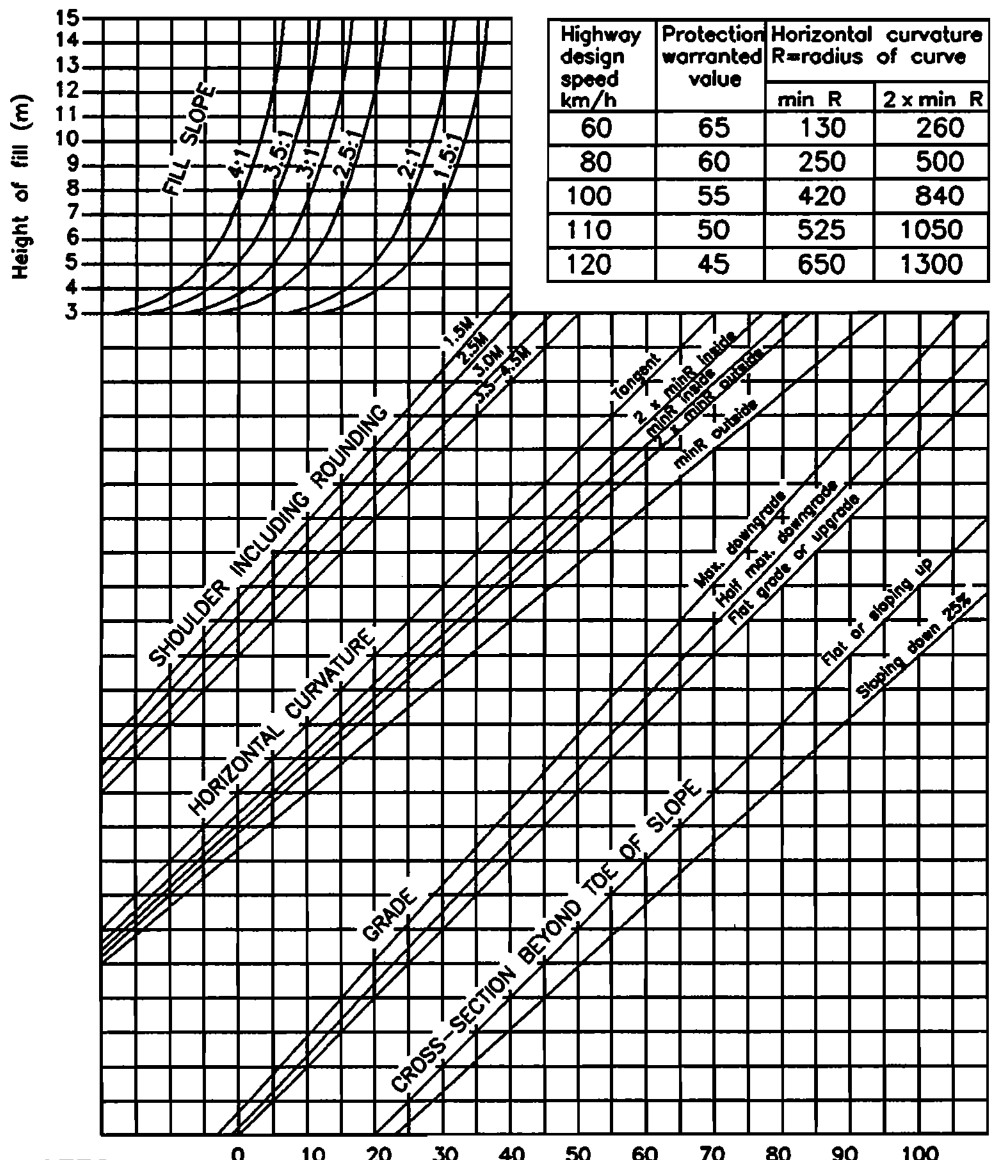
The installations of guide rail on embankments is warranted only where the combination of height and slope of the embankment is a more severe hazard than the barrier system itself.
An embankment protection warrant has been developed (Fig. 2.5.1), based on accident severity, and is readily applicable for normal embankment conditions.

POLICY

THE EMBANKMENT WARRANT GUIDE, FIGURE 2.5.1, SHALL BE USED TO DETERMINE IF PROTECTION IS WARRANTED.

LOW VOLUME ROADS

The ministry is currently conducting researching to establish warrants for embankment protection based also on traffic volumes. When completed these warrants will replace our present embankment warrant guide.



Highway design speed km/h	Protection warranted value	Horizontal curvature R=radius of curve	
		min R	2 x min R
60	65	130	260
80	60	250	500
100	55	420	840
110	50	525	1050
120	45	650	1300

EMBANKMENT PROTECTION
WARRANT GUIDE

NOTES:

1 Guide rail is not required for:

Undivided Hwys
- On fill heights less than 3 metres.
- Slopes 3:1 or flatter.

Divided Hwys
- On fill heights less than 2 metres.
- Slopes 4:1 or flatter.

2 When the embankment protection index is greater than the protection warranted value guide rail or slope flattening is required.

FIGURE 2.5.1 Embankment Warrant Guide

APPLICATION OF EMBANKMENT WARRANT GUIDE

In order to use the warrant, the slope surface texture is assumed to be free of bare rock, boulders or other obstacles. Bare rock fills must be regarded as hazards beyond the scope of the Embankment Protection Warrant and such fills below 3.0 m in depth should be flattened with earth to 3:1 slopes or flatter, or protected by guide rail, whichever is the more economical. Refer to Section 2.5.2.

To determine whether or not embankment protection is required at a specific location, the Embankment Protection Warrant Guide is used as follows:

(a) Commence at height of fill in the upper left corner of the chart and draw a horizontal line to the applicable fill slope line.

(b) Project a line down to the shoulder width line.

(c) Project horizontally to "Horizontal Curvature".

(d) Project vertically to "Grade".

(e) Project horizontally to "Cross-Section Beyond Toe of Slope".

(f) Project down to find the Embankment Protection Index.

If the Embankment Protection Index is above the Protection Warrant Value indicated on the table in Fig. 2.5.1 then the Embankment becomes an "Area of Concern" and warrants protection. The designer now has two options:

(1) to install a barrier, or

(2) to flatten the embankment slope.

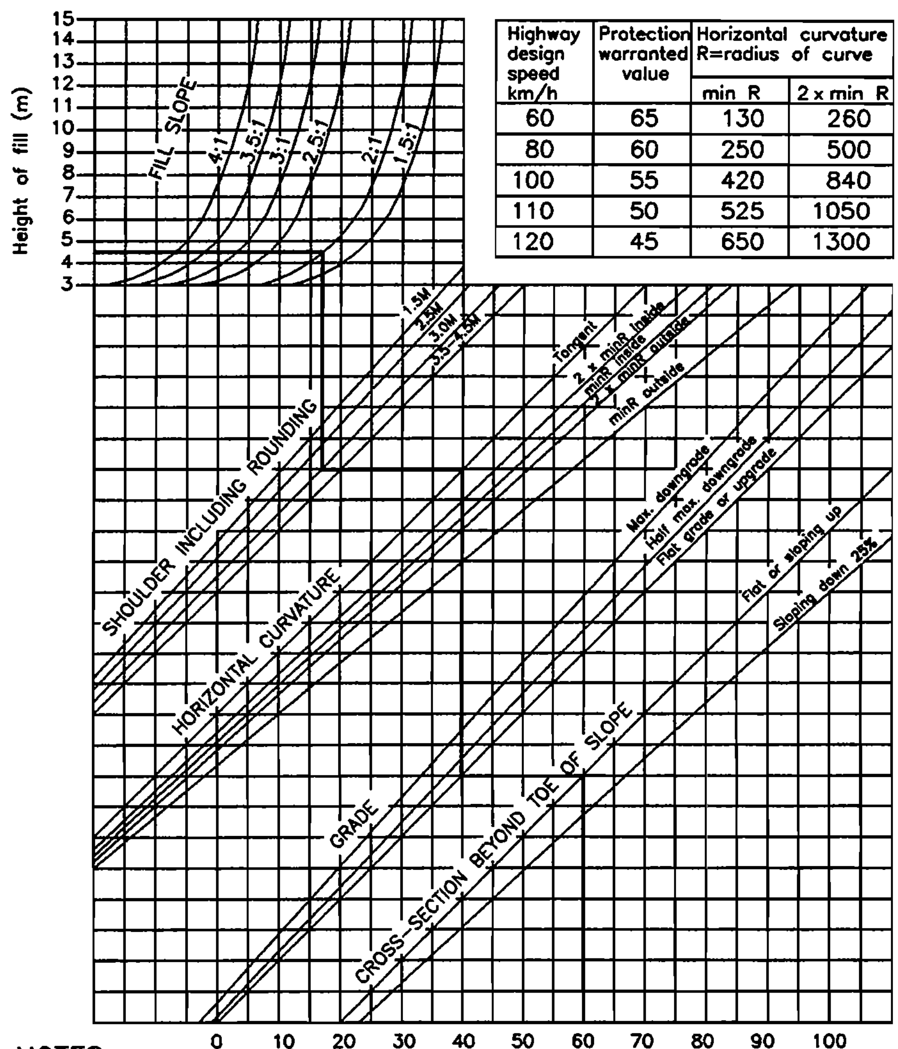
EXAMPLE 1

Review the need for Embankment Protection.

Existing two lane highway.	
Design Speed	100 km/hr
Therefore "Protection Warrant Value"	55
(from Fig. 2.5.1, inset)	
Height of Fill	4.5 m
Fill Slope	2:1
Length of Embankment	150 m
Shoulder	2.5 m + 0.5 m = 3 m
(inc. 0.5 m rounding)	
Horizontal Curvature	Tangent
Grade	Flat
Roadside	Traversable
(i.e. free of obstacles or abrupt changes of grade)	

Resulting Embankment Protection Index 60
Which is greater than "Protection Warranted Value"
= 55 so protection is warranted.

Refer to Figure 2.5.2 for the above example



Highway design speed km/h	Protection warranted value	Horizontal curvature R=radius of curve	
		min R	2 x min R
60	65	130	260
80	60	250	500
100	55	420	840
110	50	525	1050
120	45	650	1300

EMBANKMENT PROTECTION WARRANT GUIDE

NOTES:

1 Guide rail is not required for:

Undivided Hwys
- On fill heights less than 3 metres.
- Slopes 3:1 or flatter.

Divided Hwys
- On fill heights less than 2 metres.
- Slopes 4:1 or flatter.

2 When the embankment protection index is greater than the protection warranted value guide rail or slope flattening is required.

Figure 2.5.2 Determination of Embankment Protection Warrant-Example 1

EXAMPLE 2

Find the minimum cross slope for which a guide rail is not required for the above example.

(a) Commence at bottom of chart with the known Protection Warrant Value

(b) Follow the reverse course of projection up to the fill slope diagram.

(c) Find slope ratio for the corresponding height of fill.

If necessary, interpolate visually between the slope lines. Guide rail will not be required for any slope flatter than this derived value.

CONSIDERATIONS

If in the above examples the roadside beyond the toe of fill was non-traversable and embankment protection is warranted, flattening the side slope alone would not protect the embankment. If flattened, the side slope would provide a traversable area that directs the errant vehicle onto a roadside that is non-traversable and hazardous. The solution in this case is to either make the roadside traversable and then flatten the side slope, or place guide rail. The cost of flattening the side slope will depend largely on the availability of fill and/or property. A comparison of this cost with the life cycle cost of a barrier system will show which solution is more economical.

EXAMPLE 3

Existing two lane highway.		
Design Speed		100 km/hr
Therefore "Protection Warrant Value" (from Fig. 2.5.1, inset)		55
Height of Fill		4.5 m
Fill Slope		3.5:1
Length of Embankment		150 m
Shoulder (inc. 0.5 m rounding)	2.5 m + 0.5 m = 3 m	
Horizontal Curvature	Tangent	
Grade	Flat	
Roadside (i.e. free of obstacles or abrupt changes of grade)	Traversable - non recoverable	
Large body of water 2 m beyond the toe of slope		

The chart indicates that the embankment does not require protection However, since the slope is not recoverable and an errant vehicle is likely to reach the bottom, a clear zone must be added at the toe of slope (see Section 2.2). Design speed used for clear zone is 100 - 20 = 80 km/h. Clear zone width for 80 km/h is 5 m, which is greater than the 2 m offset to the body of water from the toe of slope. Therefore protection is warranted. To calculate the length of guide rail installation required, refer to Chapter 3, Section 3.4.

EMBANKMENTS PERPENDICULAR TO THE FLOW OF TRAFFIC

Embankments at T intersections, at intersecting roadways and at entrances are typically struck head on by errant vehicles. To lessen the probability of ramping, or abrupt stops if the slope of the intersecting embankment is steep enough, the slopes should be flattened to 4:1 or flatter. If slopes can not be accommodated, protection may be warranted. Refer also to Chapter 2.0 Section 2.7.1.

If the toe of embankments at overhead structures falls within the clear zone, they should be protected.

2.5.2 ROCK EMBANKMENTS

Exposed rock fills, regardless of slope, are not traversable, and are therefore considered to be a hazard. They must be protected when they are within the clear zone. Since rock fills of any depth are not traversable, the warrant for earth embankment protection does not apply.

Tests show that when guide rail deflects more than 0.6 m beyond the top of an embankment, the vehicle wheel will drop causing substantial roll. This is not a particularly serious problem where the embankment slope is relatively smooth. The errant vehicle will be re-directed safely to the shoulder. However, if snagging can occur such as on rock fills there is a very real danger of vaulting or rollovers.

POLICY

ON NEW HIGHWAY OR RE-ALIGNMENT PROJECTS, WHERE SLOPE FLATTENING IS NOT A PRACTICAL OPTION THE OFFSET FROM THE DEFLECTED FACE OF THE GUIDE RAIL BEYOND THE TOP OF THE ROCK EMBANKMENT SHOULD BE NO GREATER THAN 0.6 METRES, OR THE EMBANKMENT WITHIN THE DEFLECTION AREA OF THE GUIDE RAIL SHOULD BE MADE TRAVERSABLE WITH PROTRUSIONS NO GREATER THAN 0.15 M.

Refer to Figure 2.5.3 for illustration of the above offset, and Chapter 4.0 for deflections of the various barrier systems.

ON REHABILITATION PROJECTS, WHERE SLOPE FLATTENING IS NOT A PRACTICAL OPTION, THE DESIGNER MAY DEFER GUIDE RAIL PLACEMENT OR GRADING OPERATIONS PROVIDED THE LOCATION HAS NO EVIDENCE OF OPERATIONAL PROBLEMS.

COMMENTARY

Rather than provide protection with guide rails, it is preferable to make the slopes of the rock fill traversable by flattening with earth to slopes of 3:1 or flatter. The cost of this option should be compared to the life cycle cost of the barrier selected. Refer to Chapter 2.0, Section 2.14. Please note that rock embankments less than 2.0 m in depth require flattening to 4:1. Refer to the OPS grading drawings.

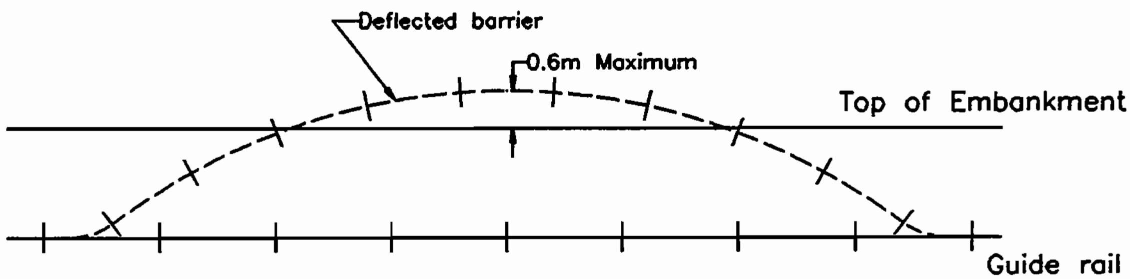


Figure 2.5.3 Maximum Barrier Deflection on Rock Embankments

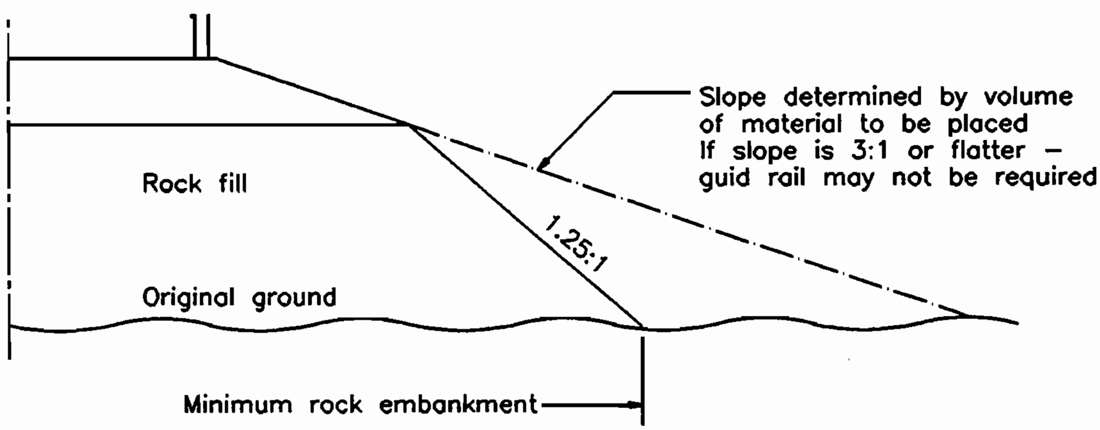


Figure 2.5.4 Rock Embankment Flattened with Surplus Fill

2.6 CUTS

2.6.1 EARTH CUT

When a roadway is in an earth cut section, the backslope parallel to the roadway may be traversable depending on its relative smoothness and the presence of fixed objects.

GUIDELINE

If the slope between the roadway and the start of the backslope, and the backslope itself is obstacle free within the clear zone, the earth cut is not considered to be a serious hazard and protection is not warranted. Transitions between slopes should be smoothly rounded, and abrupt changes in slope must be avoided. Large boulders in the backslope on which the vehicle may snag should be removed.

2.6.2 ROCK CUT

In the pre-cambrian shield area of the province there are many existing rock cuts along roadways. The likelihood of these being involved in a single vehicle accident may be somewhat less than for other less obvious hazards, since the driver may be more alert due to the visibility of the steep backslopes. Driver expectancy and awareness play a significant role in accident likelihood.

Removal of rock to satisfy full clear zone requirements is not cost effective if rock quantities are relatively small and there is no evidence of an operational problem.

POLICY

ON NEW OR MAJOR RECONSTRUCTION PROJECTS, ROCK SHALL BE REMOVED TO THE CLEAR ZONE OFFSETS SPECIFIED IN SECTION 2.2, OR SHIELDED WITH A BARRIER, WHICHEVER IS MOST COST EFFECTIVE.

ON RESURFACING OR MINOR RECONSTRUCTION PROJECTS WHERE THE ROCK CUT ITEM WOULD BE INTRODUCED DUE SOLELY TO THE POLICIES OUTLINED IN THIS MANUAL, THE DESIGNER MAY DEFER SUCH MEASURES PROVIDED THE LOCATION HAS NO EVIDENCE OF OPERATIONAL PROBLEMS.

NOT WITHSTANDING THE ABOVE POLICY, ISOLATED ROCK OUTCROPS WITH FACE PERPENDICULAR TO ONCOMING TRAFFIC ARE CONSIDERED HAZARDOUS PARTICULARLY WHEN LOCATED ON OR NEAR A CURVE, AND SHOULD BE REMOVED OR SHIELDED.

2.7 DRAINAGE RELATED HAZARDS

Effective drainage is one of the most critical elements in the design of a highway or roadway. Drainage features should also be designed, constructed and maintained with consideration for roadside safety. Thus ditches, pipes, culverts, headwalls, ditch inlets and catch basins, as well as curbs, should be designed and built with both hydraulic efficiency and roadside safety in mind. Refer to the MTO Drainage Manual for guidance on the planning and design of drainage facilities.

2.7.1 DITCHES

The primary function of a roadside ditch is to collect and convey water along the highway right-of-way until it can be drained away from the roadbed, and in most cases away from 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 their effect on roadside safety.

GUIDELINE

Roadside ditches are to be built to the appropriate grading standard drawings contained in the OPSD manual. However, in fill sections every effort should be made to maximize the distance from the toe of the slope to the ditch line, and to minimize the angle of the front and back slopes.

In a cut section, the backslope should be flatter than the minimum value shown on the OPSD's drawings, if possible, taking into account the adjacent property limits, cost of excavating, etc.

Roadside ditches should be made as shallow as possible, while still meeting the hydraulic requirements.

Front and backslopes of median ditches within the clear zone should be as flat as possible, but not steeper than 4:1. If the top of the ditch slope is beyond the clear zone, slopes may be increased to 2:1, however flatter is better.

Ditches transverse to the roadway are generally critical to errant motorists because the banks of these ditches are typically struck head on by run-off-the-road vehicles. **If banks of these transverse ditches deeper than 0.75 m cannot be flattened to slopes of 4:1, or preferably less, they should be shielded by a roadside barrier.** The length and position of the installation are to be calculated as detailed in Chapter 3, Section 3.4.

Similarly when ditches parallel to the through roadway cross intersecting roadways or driveways, errant vehicles tend to follow the ditch line. The embankments and the culverts through them are potentially struck head on. To lessen the chance of ramping over the embankments or snagging, the ditches should be placed at the maximum offset allowed by the property limits. **The sideslopes of the intersecting roadways or entrances should be flattened to 4:1 or flatter and culverts constructed with tapered ends.** The designer should ensure, however, that the hydraulic capacity of the ditch is not adversely affected.

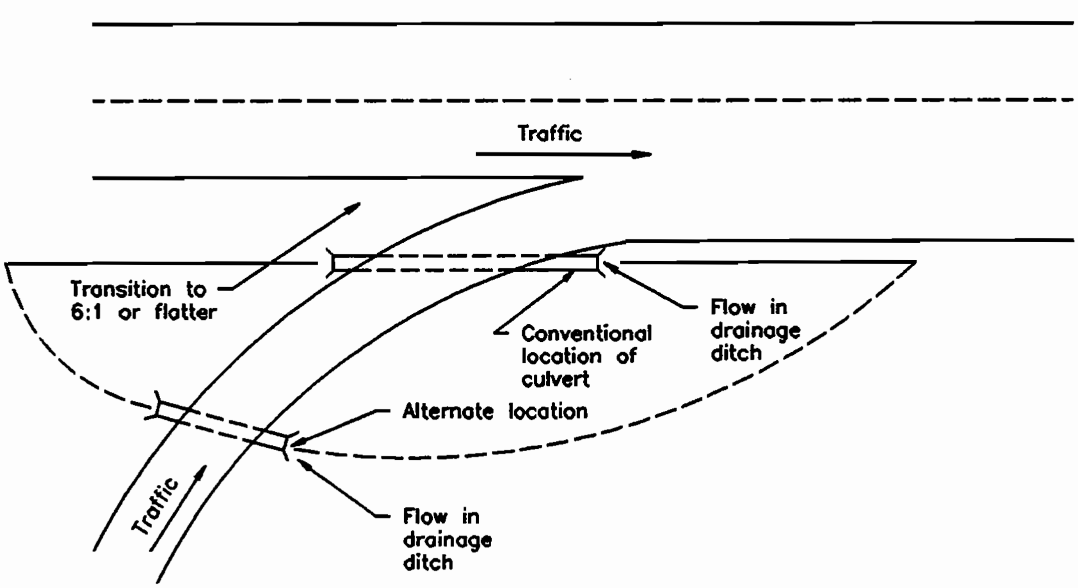


Figure 2.7.1 Alternative drainage location

2.7.2 PIPES, CULVERTS AND DITCH INLETS

Pipes and culverts are primarily designed to carry water underneath the roadway embankments, and through intersecting roadways or entrances. They vary in size from approximately 500 mm single pipes, to large structural plate or concrete culverts. Designers should consider making them traversable, to prevent abrupt speed changes or rollovers caused by snagging.

GUIDELINE

If the slope is generally traversable and barriers are not required for other purposes, the preferred treatment is to match the inlet and outlet slope of the pipe or culvert to the embankment slope. This should be done not only for culverts through the roadway, but also for culverts parallel to the road, such as at sideroad and entrance crossings. Matching the culvert end to the slope results in a smaller target for an errant vehicle, and also simplifies mowing operations.

Culverts with tapered end sections, and those with a diameter or span of 1.0 m or less, are considered to be traversable. Culverts with a diameter or span of less than 1.0 m at locations which have a potential for head on impacts such as at T intersections or entrances, should have a tapered end section. Culverts greater than 1.0 m in diameter or span can be made traversable by adding of a ride-over grate. Standards and guidelines for their applications will be issued at a later date.

Figure 2.7.2 shows an installed end section. Standards for tapered end treatments of steel culverts can be found in the OPSD manual.

Major culverts whose end section cannot be made traversable must be shielded with an appropriate length of barrier. (Refer to Section 3.4)

Ditch inlets are used in medians of divided roadways and in roadside ditches. While their purpose is to collect runoff, they should also be placed to minimize the opportunity for impact. This may be accomplished by placing them flush with the adjacent slope, Figure 2.7.3. If they must be placed parallel to the roadway, they should be placed at a minimum grating slope that is compatible with hydraulic principles. Refer to the appropriate standards in the OPSD manual for design details.

Headwalls should not protrude more than 100 mm above the surrounding terrain.

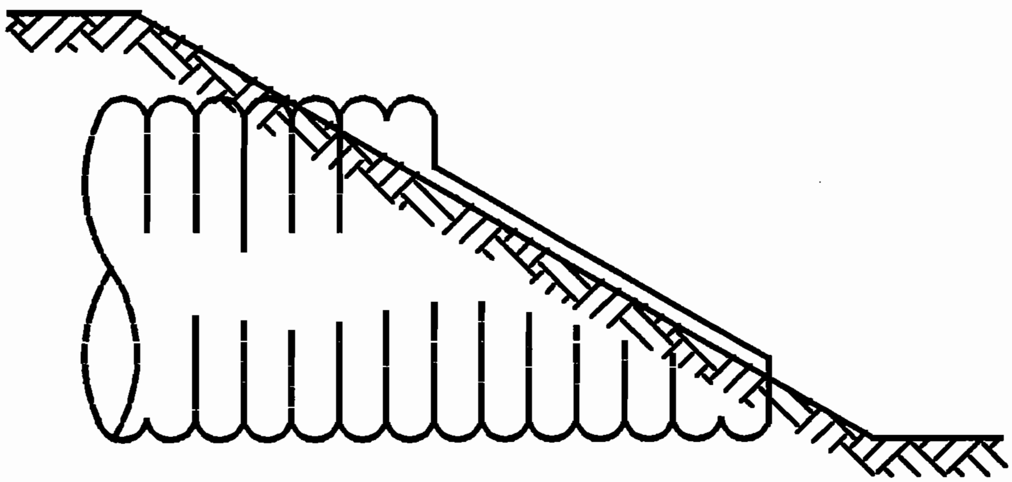


Figure 2.7.2 Tapered End Section

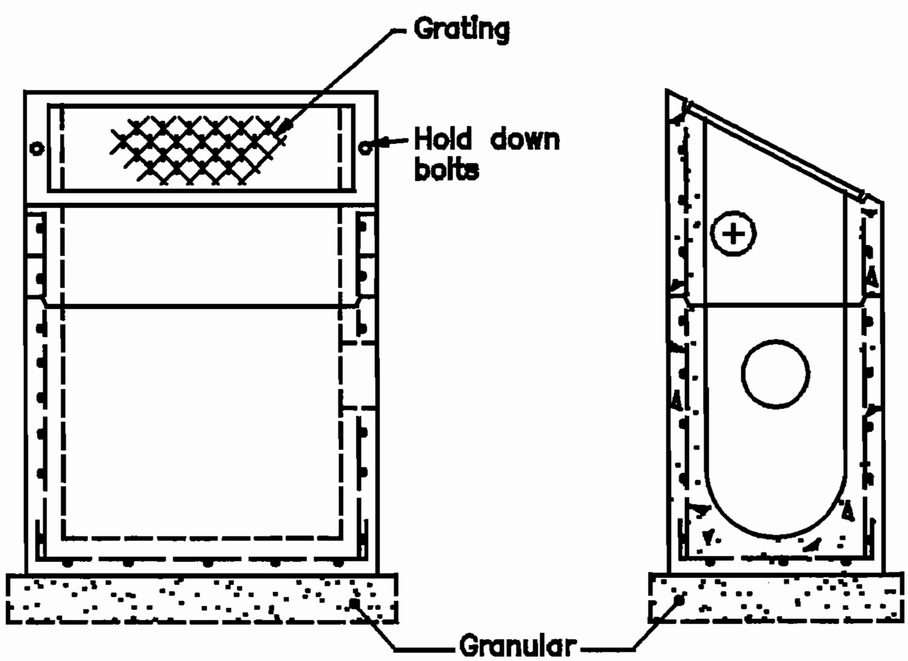


Figure 2.7.3 Ditch Inlet

2.7.3 CURBS

Curbs are commonly used to control drainage and reduce maintenance operations. They are classed as either barrier, semi mountable, or mountable. Although they are undesirable on high speed roadways, curbs cannot be completely avoided either on high speed or lower speed roadways.

If a vehicle is spinning or slipping sideways, impact with a curb could cause it to trip and overturn. Other impact conditions may cause a vehicle to become airborne, resulting in loss of control by the motorist. It is impossible to determine with any confidence how an errant vehicle, having come in contact with a curb, will interact with a barrier system in such cases.

GUIDELINE

Barrier curb is ineffective as a vehicle restraining system at speeds greater than 60 kilometres per hour, and should not be used for such purposes.

Curb and gutter, unless absolutely necessary, should not be placed adjacent to barrier systems or end treatments and energy attenuators. This is especially true on high speed roadways, where every effort should be made to design without curbs. The designer should review the site to determine if existing curb and gutter installations can be removed. Care must be taken to provide for drainage if gutters are not provided.

If the use of curbs cannot be avoided the designer should consult Table 2.7.1 for the appropriate guide rail system and type of curb and gutter to be used, and the required offsets.

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

Table 2.7.1

Summary of Guide Rail Used in Conjunction With Curb and Gutter

	MOUNT C & G	SEMI MOUNT C & G	BARRIER CURB
CABLE	no	no	no
BOX BEAM	yes	no	no
STEEL BEAM	no	no	no
STEEL BEAM WITH CHANNEL *	yes	yes	yes
IBC	no	no	no
CONCRETE	no	no	no

* With barrier type curb and gutter the Steel Beam guide rail with channel must be mounted within 250 mm. See Figure 2.7.4 for measuring points. With mountable or semi-mountable curb and gutter it is desirable to maintain the above dimension. However, it is also permissable to place the steel beam guide rail with channel any distance beyond.

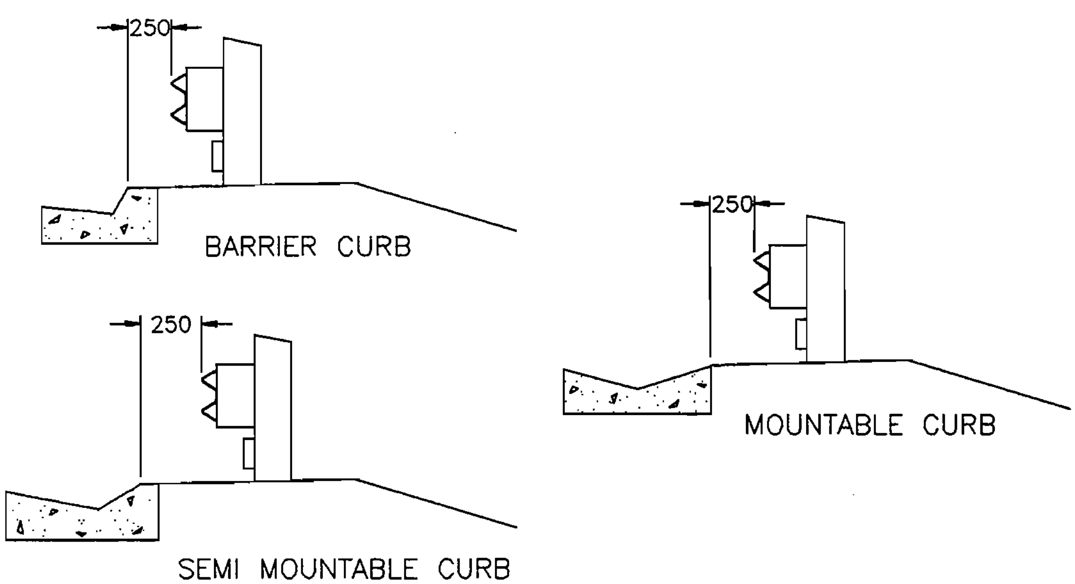


Figure 2.7.4 Offset from Guide Rail to Curb and Gutter

2.7.4 CONTINUOUS BARRIER IN OVERLAND FLOW ROUTES OR FLOOD PLAINS

If solid, continuous traffic barriers such as the concrete and IBC barrier systems or noise barriers are located at water crossings or on overland flow routes, they may act as a dam during a major storm. These dammed up flood waters may create a serious hazard to motorist, result in serious flooding upstream of the installation, causing major property damage, and may also paralyse emergency services which may result in loss of life.

POLICY

THE DESIGNER MUST CONSIDER THE IMPACT THE IMPERMEABLE BARRIER MAY HAVE DURING MAJOR FLOODS. This does not preclude the use of impermeable barriers. Increasing the capacity of the culvert or structure under the roadway could have the desired effect. Designers should consult the MTO DRAINAGE MANUAL and, if necessary, obtain technical advice from the Drainage and Hydrology Section, Surveys and Design Office.

Other alternatives may be to leave openings at the base of the barrier system, or use a non-standard thrie beam barrier. Designers should contact the Surveys and Design Office for customized design assistance.

2.8 STRUCTURES

The design of structures and components, which includes barrier walls is governed by the Ontario Highway Bridge Design Code. Therefore any and all work at or on structures must be reviewed by the Structural Section.

2.8.1 CONNECTION TO STRUCTURES

Bridge abutments and barrier walls present some of the greatest highway hazards. Due to their rigid and massive design, deceleration forces upon impact are intolerable to the human body, even at relatively slow speeds.

The main criteria in placing the guide rail on structure approaches are to make the installation long enough in case of an entry behind the barrier, to make the transition from guide rail to structure rigid enough to reduce the deflection that may cause vehicles to pocket or snag where the installation abuts the structure, and to make the connection strong enough to withstand the tensile forces created during impact.

On existing structures where it is suspected that the bridge barrier wall may not be sufficiently strong to withstand forces during an impact, the Structural Section shall be contacted.

POLICY

APPROACH END CONNECTIONS

STEEL BEAM

TO ENSURE A GRADUAL INCREASE IN RIGIDITY AT THE CONNECTION, POST SPACING IS REDUCED, AND CHANNEL IS ADDED.

The connection itself consists of two overlain steel beam elements and an end piece. It is imperative that the rail and channel be properly anchored to the structure and smoothly transitioned to it, to prevent snagging. Anchorage assemblies specified by the Ministry are designed to equal the tensile strength developed in the barrier under design impact. Figure 2.8.1 shows details of the connection of steel beam to one type of structure. Refer to the OPSD Manual for other applications.

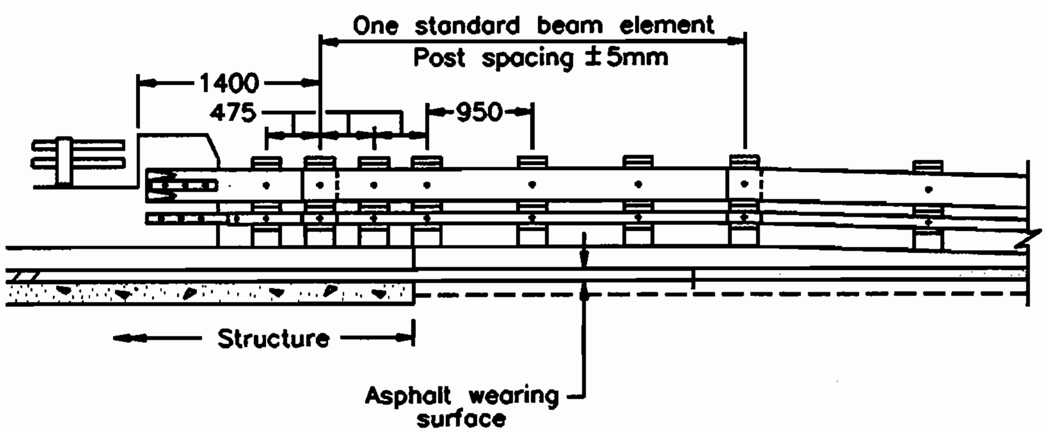


Figure 2.8.1 Details of Steel Beam Connection to Structure
Note the reduced post spacing and the additional beam element.

Any deviation from the standards shown in the OPSD manual that result in a lower level of protection must not occur. If posts cannot be installed at the proper spacing due to site conditions, additional beam and channel elements may be required to give the systems sufficient strength and rigidity. **If post spacing within 2.0 metres of the connection is greater than 1.0 metre, an additional steel beam element should be placed at the connection.**

Connections to structures as shown on the Ontario Provincial Standard Drawings must be used both for new and existing structure connections. On existing structures which do not require rehabilitation, the former butt-ended connection may remain in place if it appears to be structurally sound. The post spacing, however, must be correct.

NOTE: For lengths of steel beam guide rail systems when connected to structures or other rigid objects, refer to Chapter 3.0, Section 3.4.1.

CONCRETE

WHEN CONCRETE BARRIER IS CONNECTED TO A STRUCTURE, A DOWEL CONNECTION AS SHOWN IN THE OPSD MANUAL MUST BE USED.

BOX BEAM

TO ENSURE PROPER BEHAVIOUR AT THE CONNECTION, POST SPACING IS REDUCED AND AN ADDITIONAL BEAM IS ADDED. Refer to OPSD 914.11 to 914.14 and Figure 2.8.4.

CABLE

UNDER NO CIRCUMSTANCES SHALL CABLE BE CONNECTED DIRECTLY TO A RIGID ROADSIDE OBJECT, SUCH AS STRUCTURE ABUTMENTS, BARRIERS, ETC.

POLICY

LEAVING END CONNECTIONS

CONNECTION OF GUIDE RAIL TO THE LEAVING END OF THE STRUCTURE IS IDENTICAL TO THE APPROACH END.

However, on four or more lane highways divided by a median, a barrier will not be required on the leaving end of structures when embankment protection is not warranted by the embankment protection warrant guide and/or median protection warrants. If a guide rail is warranted, and large deflections can be tolerated, a cable guide rail may be used but must be transitioned from steel beam, never transitioned directly from the structure. Refer to leaving end treatments, Chapter 2.4. Please note that an eccentric loader or equivalent treatment is not required, if the end of the system cannot be struck by an approaching vehicle.

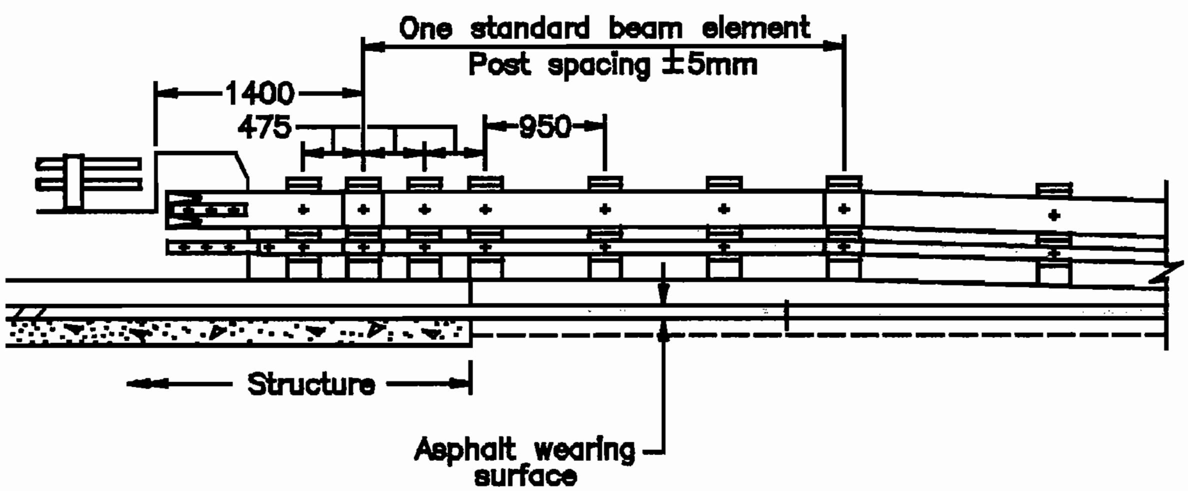


Figure 2.8.2 Typical Connection to Structure - Steel Beam

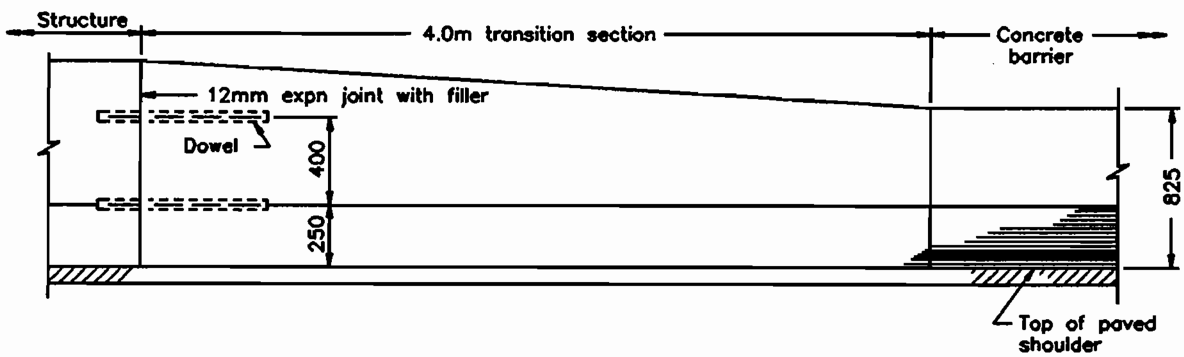


Figure 2.8.3 Typical Connection to Structure - Concrete

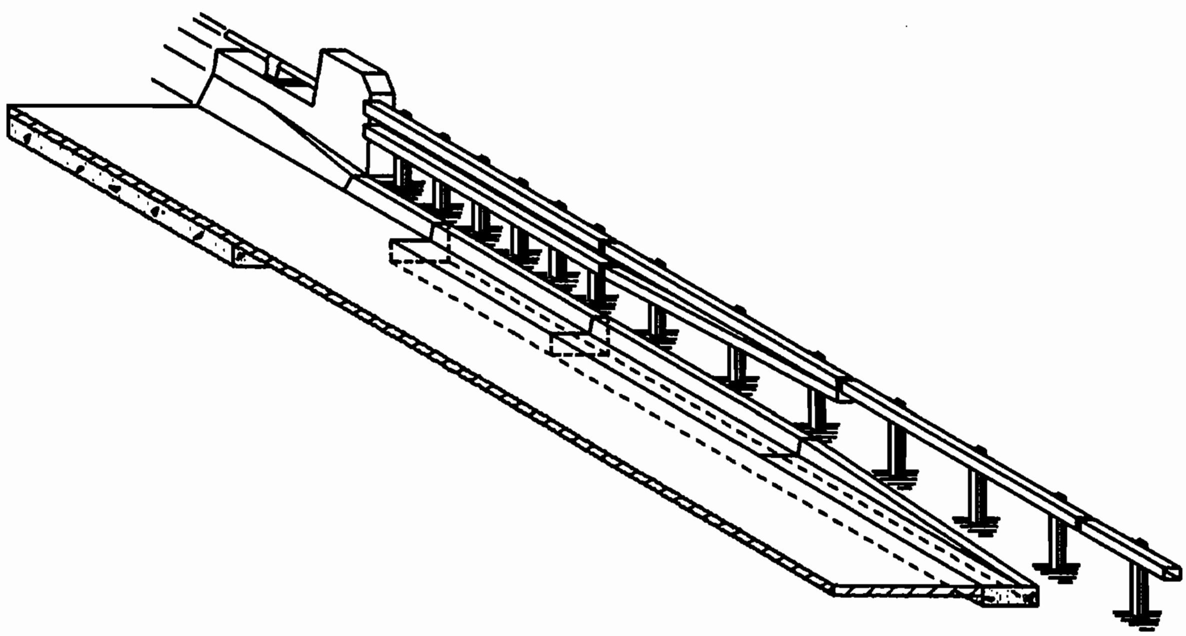


Figure 2.8.4 Typical Connection to Structure - Box Beam

2.8.2 TWIN STRUCTURES

Approaches to twin structures are an extreme hazard. The ends of the barrier walls, as well as the area between, must be protected to prevent errant vehicles from entering behind the guide rail and entering the hazard area between the structures.

POLICY

ALL APPROACH TREATMENTS TO TWIN STRUCTURES SHALL BE DESIGNED WITH EITHER:

(1) RIGID OR SEMI-RIGID LONGITUDINAL BARRIER,

OR

(2) CRASH CUSHION.

The choice of treatment is often dictated by the site geometry. If both solutions are feasible, a cost comparison should be done to select the appropriate protection measure.

LONGITUDINAL BARRIER

IN THE TREATMENT OF TWIN STRUCTURES WITHIN THE MEDIAN, THE INSTALLATION LENGTH OF THE BARRIER INCLUDING THE END TREATMENT SHALL BE THE FULL ENCROACHMENT DISTANCE SHOWN ON TABLE 3.4.1, CHAPTER 3.0. This is the only case where the full encroachment length is used as the length of installation. For other cases, refer to Chapter 3.0, Section 3.4 for installation length calculation.

Using the full encroachment length allows vehicles entering behind the guide rail system to come to a stop before they reach the hazard area between structures. In addition to the above length, a steel beam guide rail must also be installed between the structure barrier walls, perpendicular to traffic flow. The designer must ensure that the steel beam installation does not fall below the crest of the embankment. Where insufficient length is available, and no crash cushion appears suitable, the Surveys and Design Office should be contacted for a customised design.

CRASH CUSHIONS

Crash cushion installation is placed at a 10 degree angle to the approach lanes and must be of sufficient width to shield the ends of both parapet walls. A back-up structure is required unless a suitable structure is already in place and is designed to withstand vehicular impacts. The gap between the crash cushion and the backup up structure should be no greater than 0.3 metres.

Inertial barrier modules should only be used as a last resort, since they provide re-direction for an impact on the side of the cluster only at low speeds. There is insufficient mass between the point of impact and the hazard being protected to provide a safe stop.

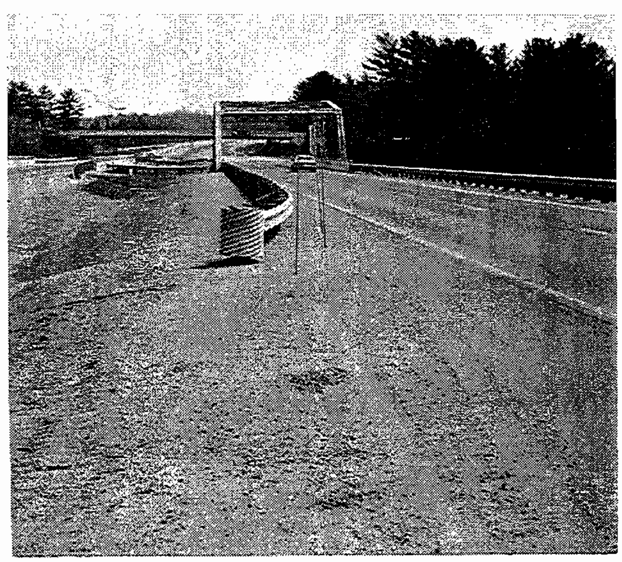


Figure 2.8.5 Twin Structure

2.8.3 SIDEWALK PROTECTION ON STRUCTURES

NOTE: Structure design and components of the structure are governed by the Ontario Highway Bridge Design Code. Therefore any and all work at or on structures must involve the Structural Section.

COMMENTARY

Typically sidewalks on structures have been placed between a barrier wall on the outside, and a barrier curb on the inside. Consideration should be given to the following.

On structures with posted speed greater than 60 km/h a mountable, rather than a semi-mountable or barrier curb is preferred adjacent to the sidewalk. Consideration should also be given to delineating the sidewalk without the use of curb of any kind.

On new structures with heavy pedestrian traffic consideration should be given to have the sidewalk behind the barrier wall and providing a light pedestrian rail on the outside.

If the barrier wall is placed adjacent to the traffic, the approach ends must be protected as for all guide rail systems.

2.8.4 PROTECTION OF ABUTMENTS, PIERS, TUNNELS AND LONG UNDERPASSES

Abutment walls and piers adjacent to roadways are a hazard if they are within the clear zone.

Note: Structure design and components are governed by the Ontario Highway Bridge Design Code. Any work at or on structures must involve the Structural Sections.

GUIDELINE

Abutments, Tunnels and Long Underpasses

The abutment faces, particularly in long tunnels and underpasses, should be shielded with a barrier system; either concrete or steel beam. The concrete barrier may be cast into the face of the abutment or placed immediately adjacent to it. These options must be discussed with the Structural Section. If steel beam is used the front face of the steel beam must be placed a minimum 0.5 metres, from the abutment face and a channel used.

It is desirable to maintain a shoulder width consistent with the approach shoulder. The designer should ensure that the minimum stopping sight distance is maintained, which is particularly important in the case of left hand curves, at long subways or tunnels.

The barrier or concrete safety shape should not be introduced at the expense of standard shoulder widths determined by the design speed of the facility. If clearance does not permit, a vertical concrete wall is an acceptable alternative to the safety shape or other barrier system.

Piers

Piers adjacent to the roadway, whether on the roadside or in the median should be shielded if they are within the clear zone width, as specified in Chapter 2, Table 2.2.1. If the piers are outside the clear zone but the cross section is such that errant vehicles may be channelled by the terrain directly into the pier, as shown in Figure 2.8.9, the designer should consider installing protection. Refer also to Chapter 2, Section 2.2.1.

Protection devices may include guide rail installed with the appropriate end treatment, or an impact attenuator such as the CIAS. Inertial Barrier Modules configured as shown in the OPSD Manual, should only be used as a last resort, since they provide no re-direction for an impact on the side of the cluster except at low speeds. There is insufficient mass between the point of impact and the hazard being protected to provide a safe stop.

When concrete barrier is used for protection, the minimum distance from the toe of the barrier to the face of the pier should be 450 mm. This is to allow for leaning of tractor trailers parked or driving on adjacent shoulders, with a standard cross-fall of six percent.

When a steel beam guide rail is installed directly on the face of pier, a proper transition must be used (refer to Section 2.8.1).

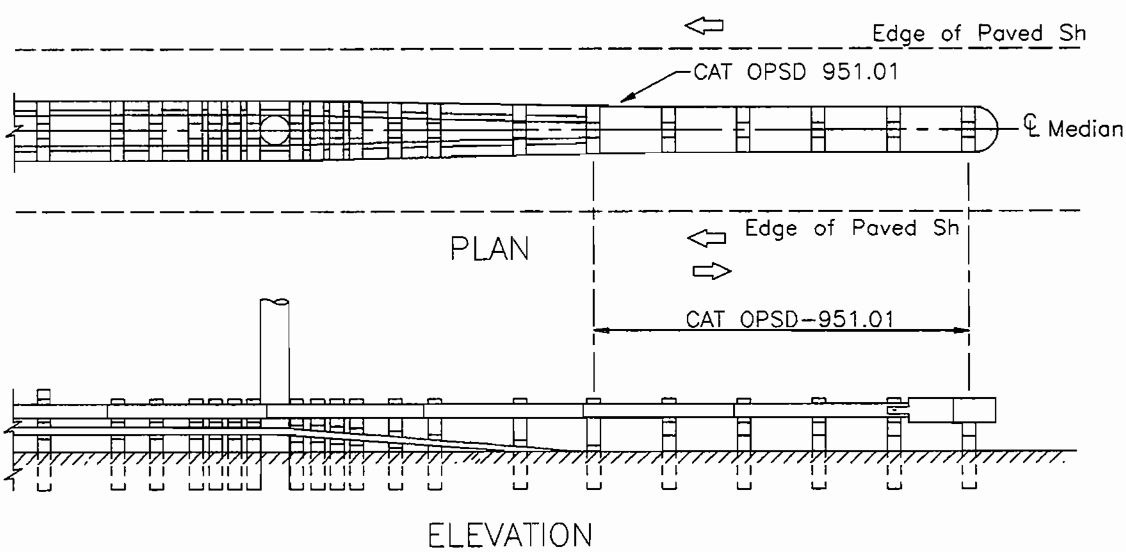


Figure 2.8.6 Steel Beam Protection of Pier

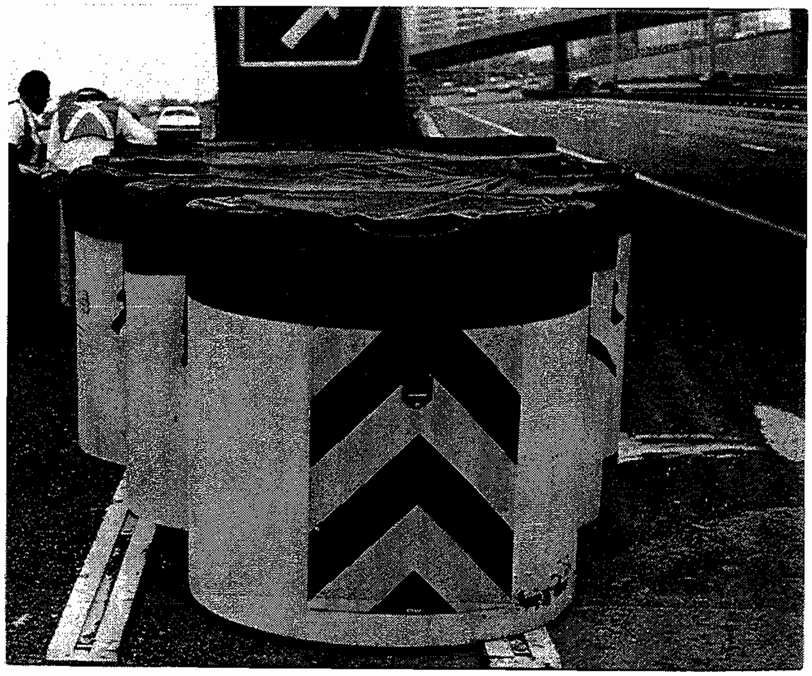


Figure 2.8.7 Pier Protected by a CIAS Installation

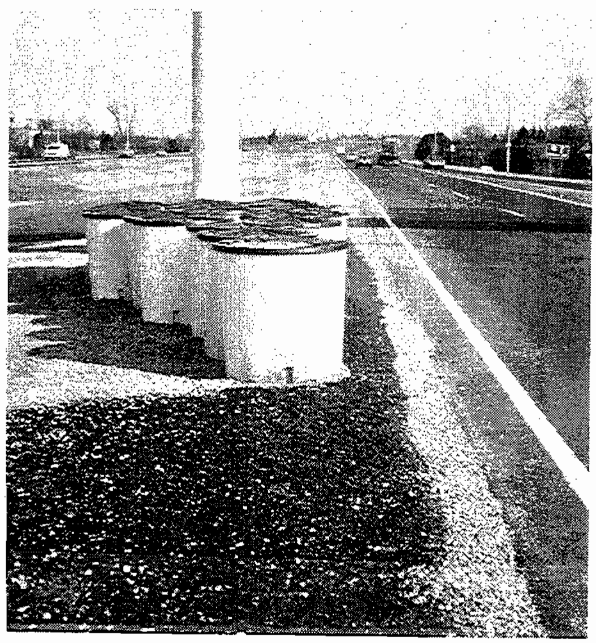


Figure 2.8.8 Pier Protected with Inertial Barrier Modules

This system should only be used if others cannot be installed.

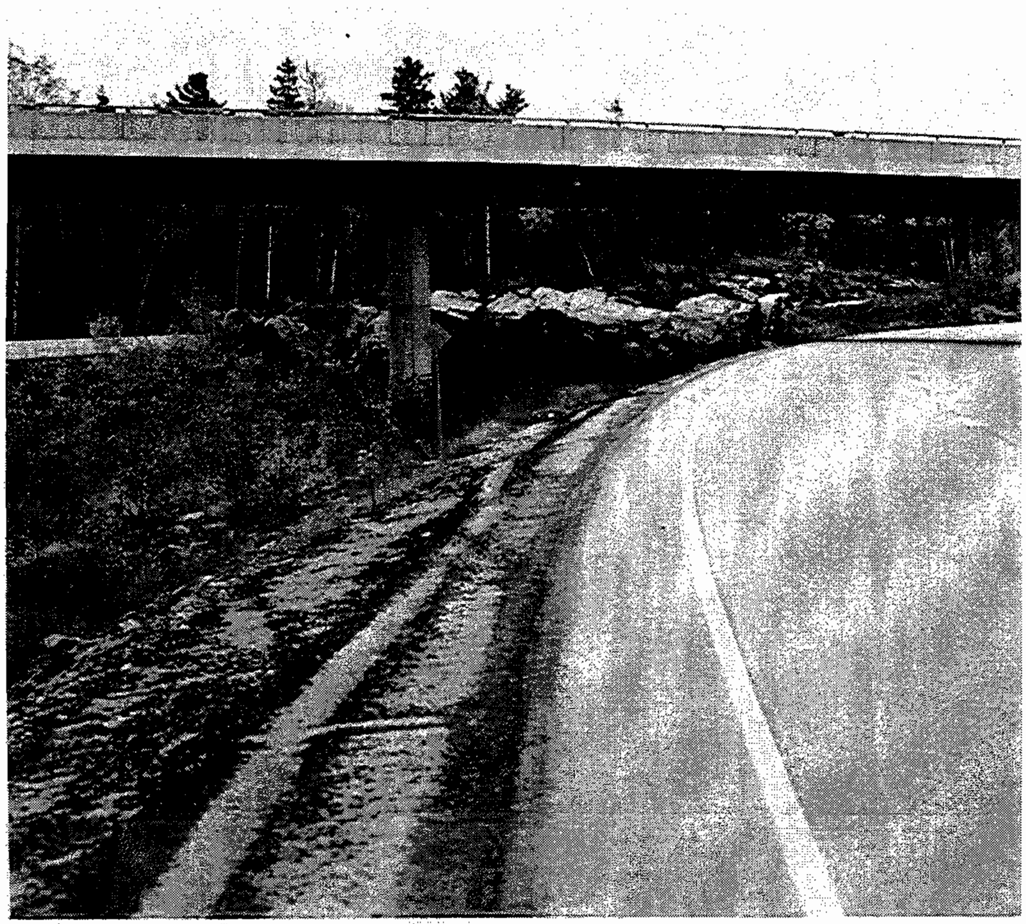


Figure 2.8.9 Potential Pier Protection

Cross-Section will tend to channel an errant vehicle directly into the pier. The designer should consider providing protection, even though the pier is beyond the hazard free zone.

2.9 INTERSECTIONS

2.9.1 RADIUS TREATMENT

Barrier protection may be required on the radius of intersecting roadways and entrances. This may occur where the facility is located on a non traversable fill, or where there is some other obstacle that may be hazardous to errant vehicles. It may also be required where the side road/entrance falls within the length of need of another hazard requiring protection.

POLICY

CABLE GUIDE RAIL IS NOT TO BE USED FOR SMALL RADIUS APPLICATIONS. STEEL BEAM BARRIERS SHOULD BE USED ON SMALL RADIUS CURVES. IF DEFLECTIONS CANNOT BE TOLERATED CONCRETE MAY BE AN ALTERNATIVE.

The Surveys and Design Office is presently evaluating barrier designs for radii treatment at shoulders of intersections. When this evaluation is complete, new OPSD drawings will be issued.

CONSIDERATIONS

It should be noted that barriers placed at intersection corners are themselves obstacles, and the indiscriminate use of barriers may well result in the creation of a hazard more severe than that which existed originally. The designer should consider alternative treatments such as flattening slopes, relocating the obstacle, relocating the entrance, or using breakaway hardware if applicable. **Where barriers are applied at intersections the designer should ensure that the driver's sight lines are not obscured.** The barrier may have to be set back to provide the required sight distance, or the intersection may need to be re-aligned.

2.9.2 T INTERSECTIONS

Guide rail systems are not designed for high angle impacts. As the impact angle increases, the guide rail is subject to increased loading and the likelihood of injury to occupants and damage to vehicles increases. A right angle impact does not allow the system to re-direct. Once the maximum deflection is reached, the vehicle may vault over, be forced under, go through the system, or come to a complete and sudden stop, with the high possibility of severe injury to the occupants.

POLICY

GUIDE RAIL SYSTEMS MUST NOT BE PLACED OPPOSITE TO T INTERSECTIONS EXCEPT AS A LAST RESORT. If the roadside of the through roadway has hazards which require shielding by a longitudinal barrier, the hazard should be relocated, removed or made breakaway.

CONSIDERATIONS

Embankments on the through road way, whether they require protection or not, should be flattened to 6:1 or less, and back slopes should be 4:1 or flatter. If it is not practical to construct embankments or backslopes to these dimensions due to property or other restrictions, it may be feasible to pipe the ditches. Consideration should also be given to relocating the intersection, or re-aligning the roadway, particularly if the intersection has been identified as having a high potential for vehicles crossing the through roadway.

Only in extreme cases such as where large bodies of water, streams, or unusual items such as the escarpment are present, a steel beam guide rail system may be considered. Wooden posts should be made breakaway to lessen the chance of override. Drawings are being prepared and will be issued in OPS format when completed.

An alternative protection measure may be to use a dragnet. See Chapter 5.0.

2.9.3 GORE AREAS

The gore area of an interchange is likely to be a high incident location, where vehicles leave the travelled way between the ramp and the through lanes. Similar situations exist where the road splits into two or more separate roadways at relatively small angles such as the transfer lanes from the core to collector or vice versa.

POLICY

THE GORE AREA SHOULD BE KEPT CLEAR OF ALL NON BREAKAWAY SIGNS AND OBSTACLES PROVIDING A FULL ENCROACHMENT LENGTH FOR A VEHICLE TO COME TO A COMPLETE STOP.

The installation of curb and gutter at these locations should be avoided. If design requires the use of curb and gutter, only the mountable type should be used. Barrier type curb and gutter must never be used at these locations, and on reconstruction projects they should be removed. If it is not possible to maintain a clear area at the gore, breakaway hardware or a barrier system in conjunction with an appropriate end treatment or crash cushion must be installed.

CONSIDERATION

If the ramp and through lanes both require longitudinal barriers, the junction of the two systems requires treatment with an approved end treatment or energy attenuator. The turned down steel beam end, or the turned down concrete barrier end, must not be used at these locations, unless the posted speed for both facilities is 60 km/h or less.

Inertial Barrier Modules should be used only at low risk locations, and only if other systems cannot be placed. They are not recommended because of the high maintenance effort required and their inability to provide re-direction except during low speed impacts. If struck on the side of the cluster there will be insufficient mass in front of the hazard to bring the errant vehicle to a safe stop. Refer to figures 2.9.1 and 2.9.2 for examples of gores protected by different energy attenuation devices.

Figure 2.9.1 Gore Area Protected with a HI-DRO System

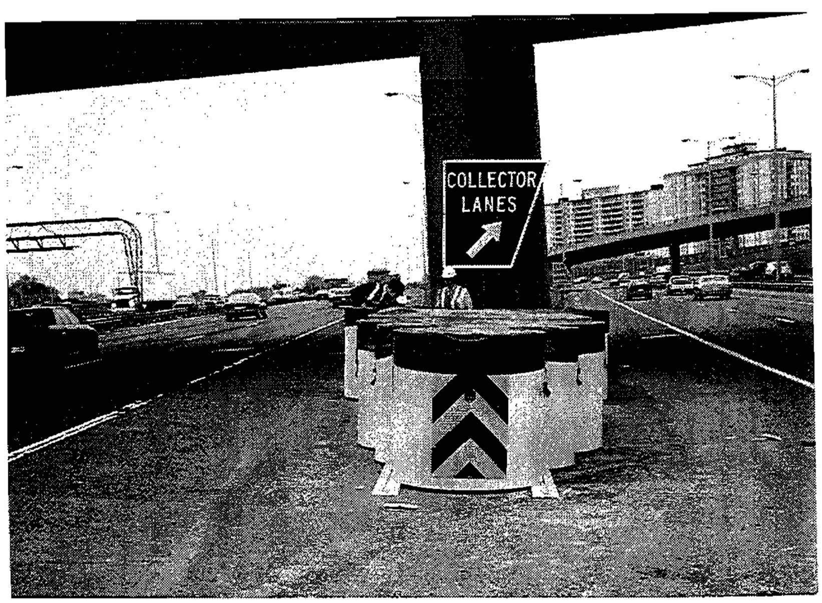


Figure 2.9.2 Gore Area Protected with a CIAS Installation

2.9.4 INTERCHANGE RAMPS AND LOOPS

Guide rail protection is warranted at interchange configurations where some of the ramps and loops are on non-traversable fill embankments, and where adjacent ramps carrying traffic in opposite directions may be separated by a lesser distance less than indicated in Table 2.2.1, of Chapter 2, Section 2.2. Storm water management ponds, which are becoming more prevalent at these locations, are also a potential hazard.

POLICY

THE RAMPS AND LOOPS OF AN INTERCHANGE WILL REQUIRE PROTECTION BASED ON THE SAME POLICIES AND GUIDELINES PROVIDED FOR THROUGH ROADWAYS, WITH EQUIVALENT DESIGN SPEEDS.

ALL FREEWAY-TO-FREEWAY INTERCHANGE RAMPS SHALL USE CONCRETE BARRIER SYSTEMS. EMBANKMENTS ON RAMPS WITH POSTED SPEED 80 KM/H OR LESS SHALL USE UNDIVIDED HIGHWAY EMBANKMENT PROTECTION WARRANT. ALL OTHER RAMPS WILL USE WARRANTS FOR DIVIDED HIGHWAY.

CONSIDERATIONS

Maintenance is a key consideration when selecting a barrier type due to the constrained space at these locations and usually high exposure to traffic.

The designer should note that on sharp curves, which are prevalent in most interchange configurations, the angle at which an errant vehicle strikes the barrier system may increase substantially thereby increasing the potential for injury and damage. For this reason the designer should make every effort to design without the use of guide rail, for example using embankment slopes of 3:1 or flatter, with a clear run out area equal to a full encroachment distance shown on Table 3.4.1., Chapter 3.0.

Box beam and cable systems should not be used at these sharp curves. Guide rail selection should be steel beam in a rural environment, and concrete in an urban environment. For barrier selection in an urban environment refer also to Chapter 2, Section 2.13.

The designer should ensure that the placement of the barrier in the narrow ramp separations conforms to the guideline for stepped medians where applicable. Refer to Chapter 2, Section 2.10.3.

Whenever a retaining wall is present, guide rail in the vicinity should be extended if necessary and properly connected or transitioned in the same manner as to a structure parapet wall. Refer to Chapter 2.0, Section 2.8.1.

On any ramps requiring guide rail protection and which have a significant volume of commercial traffic or a history of numerous accidents involving these vehicles, consideration should be given to using high performance barriers.

2.9.5 BUS SHELTERS

Bus shelters at intersections are generally not protected unless a serious operational problem exists and all other alternatives are not feasible. The installation should be located on the far side of the intersection so as not to hamper the sight distance requirements of motorists turning at stop condition sideroads.

In rural conditions bus shelters for regional transit operations should be installed beyond the clear zone offset.

2.10 MEDIAN PROTECTION

2.10.1 STANDARD MEDIAN PROTECTION WARRANTS

OVERVIEW

Median barriers are installed to prevent vehicles from crossing over the median into the path of opposing vehicles. As a head-on collision with an opposing vehicle will likely be more severe than collision with a barrier, the barrier represents the lesser hazard when considering median cross-over accidents.

There are many divided highways separated by either traversable or non-traversable medians that operate safely and provide good service for low traffic volumes. As traffic volumes increase, however, vehicle manoeuvrability decreases, and the probability of driver error, vehicle collisions and median crossovers will also rise.

If the median is wide enough and side slopes are recoverable, median barriers are not required, unless there is evidence of operational problems.

POLICY

THE MEDIAN BARRIER WARRANT GUIDE FOR DIVIDED HIGHWAYS, FIGURE 2.10.1 MUST BE USED TO DETERMINE THE NEED FOR A MEDIAN BARRIER.

Median barrier warrants are based on median width, (measured between edges of driving lanes) and predicted 10 year traffic volume (A.A.D.T.).

Justification for deviation from the median barrier warrant guide, (i.e. provision or non-provision of barriers in the Optional zones), must be documented in the design criteria, for approval by the Design Criteria Committee.

All warranted median traffic barriers, shall be constructed as part of the capital construction program, preferably in conjunction with widening or major median reconstruction.

All medians where a traffic barrier is recommended by Regional Traffic Section to resolve operational or safety problems, may justify acceleration of the construction program. If the construction program cannot be accelerated, a separate contract may be instituted for construction of the median barrier alone. The approval of the Design Criteria Committee is required.

COMMENTARY

A threshold of 20,000 AADT has been established as the level below which divided highways that operate satisfactorily do not require a median barrier. Refer to Fig 2.10.1.

The median barrier warrant guide consists of two zones where a barrier is not required.

1. Barrier Optional

    Barriers are not required and should not be installed except in special circumstances such as when a median crossover accident problem has been identified by the Regional Traffic Section, where an identified geometric deficiency cannot be readily corrected, or for continuity with adjacent sections.

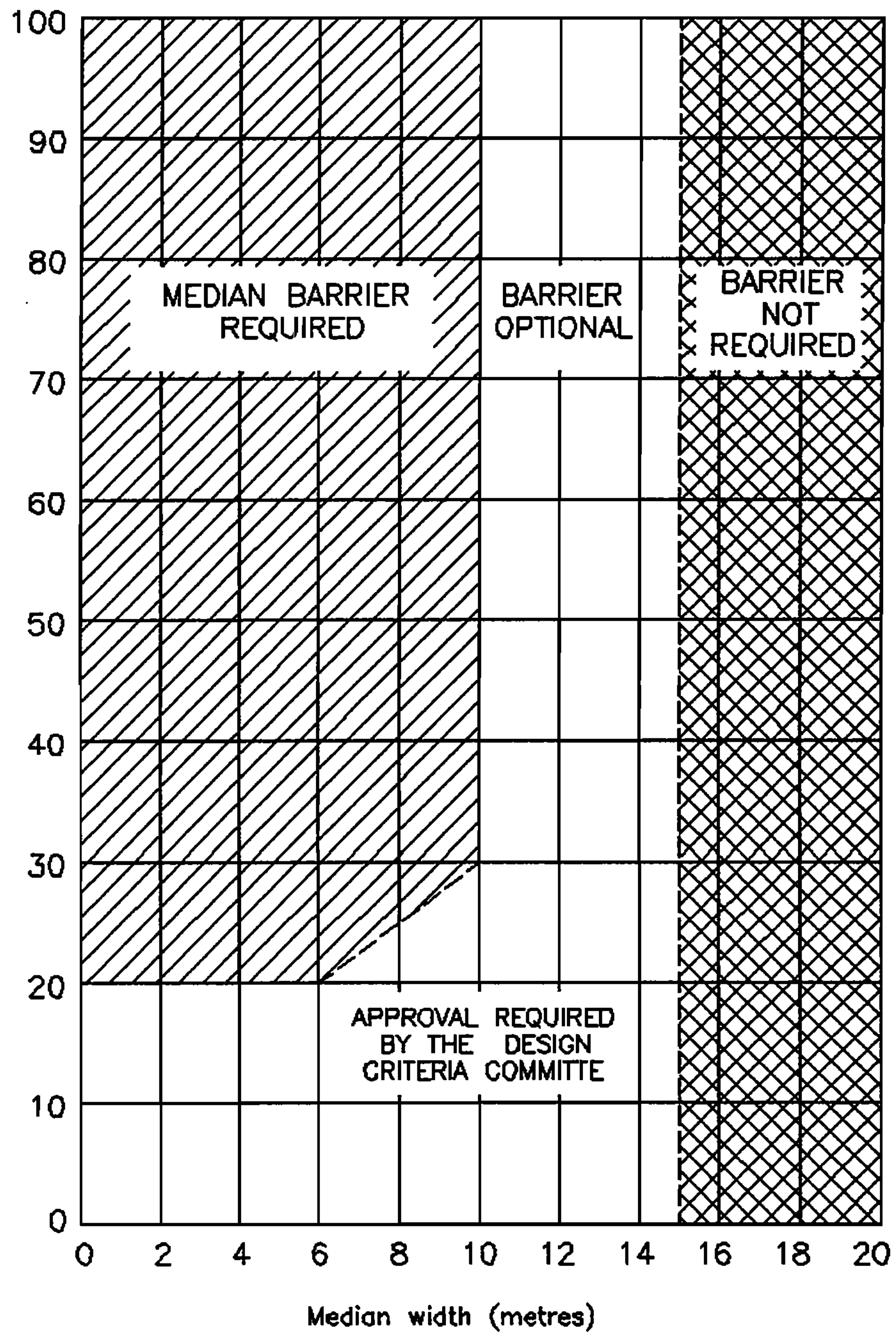


Figure 2.10.1 Median Barrier Warrant Guide for Divided Highways

2. Barrier Not Required

A median barrier is not required in medians wider than fifteen metres, since errant vehicles rarely travel this distance beyond the driving lanes. The median should, however, be as flat and free of hazards as possible to allow errant vehicles to recover. Ditch slopes in the median should be as flat as possible, but no steeper than 4:1, if within the clear zone. For medians 15 m wide or greater, including medians separating roadways at different grades, roadside hazard protection guidelines apply.

The optimum median width from a safety viewpoint is the maximum that the right-of-way can contain, thus avoiding the need for a barrier. Bridge piers or other median hazards may require individual protection. However, it is advisable to provide continuous protection if these hazards are frequent. The designer should exercise judgement about when to apply continuous protection.

2.10.2 HIGH PERFORMANCE MEDIAN PROTECTION

Traditionally, most roadside barriers were developed, tested and installed with the intention of containing and redirecting passenger vehicles weighing up to approximately 2000 kg. These barriers have proven effective in reducing the amount of damage and lessening the severity of personal injuries when struck by automobiles at relatively shallow angles and impact speeds of approximately 100 km/h.

Since these barriers cannot be expected to work equally as well for large trucks and buses, high performance barriers have been especially developed for this purpose. Two of these barriers have been approved for use on Ontario highways; the IBC MK-7HV and the Ontario Tall Wall. The Ministry has developed a warrant for these barriers based on the number of heavy vehicles in the traffic stream.

POLICY

THE HIGH PERFORMANCE BARRIER WARRANT, FIGURE 2.10.2, MUST BE USED TO DETERMINE THE NEED FOR A HIGH PERFORMANCE BARRIER. THE WARRANT DOES NOT APPLY ON DETOURS. EXISTING STANDARD CONCRETE BARRIERS NEED NOT BE UPGRADED TO HIGH PERFORMANCE BARRIERS UNLESS THE BARRIER IS BEING REMOVED FOR OTHER PURPOSES.

Approval of the Design Criteria Committee is required if the warrant indicates that protection is optional or not required, and the designer recommends high performance barrier.

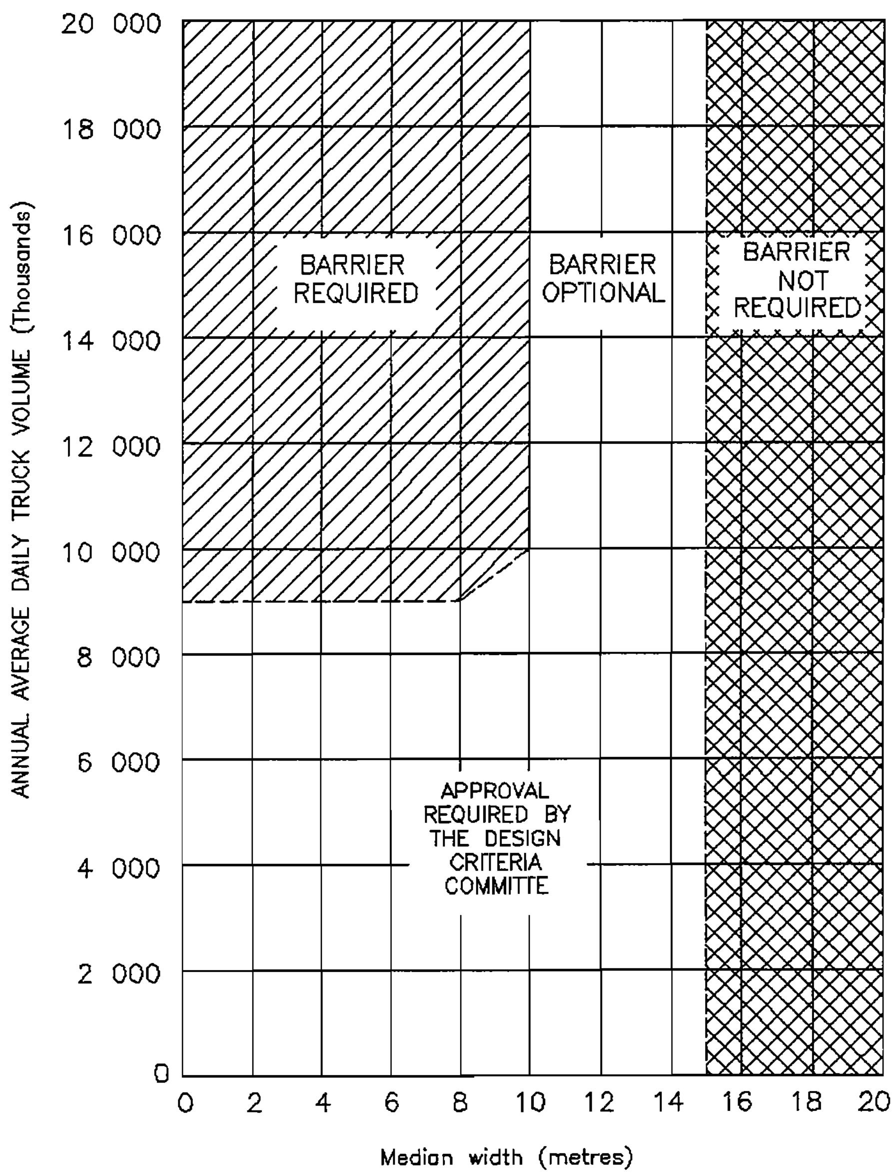


Figure 2.10.2 High Performance Barrier Warrant Guide

2.10.3 CORE COLLECTOR MEDIAN

POLICY

HIGH PERFORMANCE BARRIERS ARE NOT REQUIRED BETWEEN THE CORE AND COLLECTOR LANES.

Where both core and collector lanes are present, an equal volume split may be assumed and AADT divided by 2 for the core median warrant application, unless more accurate volume data is available.

2.10.4 STEPPED MEDIANS

Stepped medians can cause vehicles to be airborne prior to or at the time of impact with the median barrier, or to under ride the system. Consequently vehicle trajectories must be considered in selecting the type, mounting height, and location of the barriers on these medians.

GUIDELINES

The following guidelines apply to the placing of guide rail on stepped medians. Refer also to Figure 2.10.3, a to e.

a) Median slopes 6:1 or flatter.

Any median barrier system that satisfies the deflection criteria, other than concrete, can be used on a paved or unpaved surface, provided they are located a minimum of 4 metres from any surface breakpoint with a roll over between slopes that is greater than 10 percent. Concrete barrier shall be placed only on paved slopes 10:1 or flatter.

b) Median slopes between 3:1 and 6:1.

The barrier shall be placed at the higher hinge point, provided that the deflection control criterion is met.

c) Median slopes 3:1 or steeper.

A double installation of guide rails (a barrier satisfying the deflection control criteria) shall be placed at the hinge points. This option becomes more desirable as the step height increases.

d) Concrete median barrier may be used for medians with a maximum elevation difference of

600 mm measured at the centre line of the concrete barrier. To accommodate steps greater than 600 mm, a safety shaped retaining wall must be designed. IBC barrier cannot be used in this type of median.

e) Vehicle trajectories must be considered for slopes steeper than 6:1. When vehicle trajectories overlap, cable and box beam systems are not to be used in the median area.

CALCULATION

The following formula can be used for calculating vehicle trajectory, and is derived from the formula for velocity, based on a 17 degree approach angle with speed in km/h.

$$Y = sx + Kx^2$$

Where
s = slope of pavement or shoulder (m per m)
x = horizontal distance from hinge point (m)
Y = calculated vehicle trajectory (m)
K = a constant which was developed for different speeds which are given below:

Table 2.10.1 K Values at Various Design Speeds

SPEED (km/h)						
60	70	80	90	100	110	120
.2065	.1500	.1161	.0900	.0743	.0614	.0516

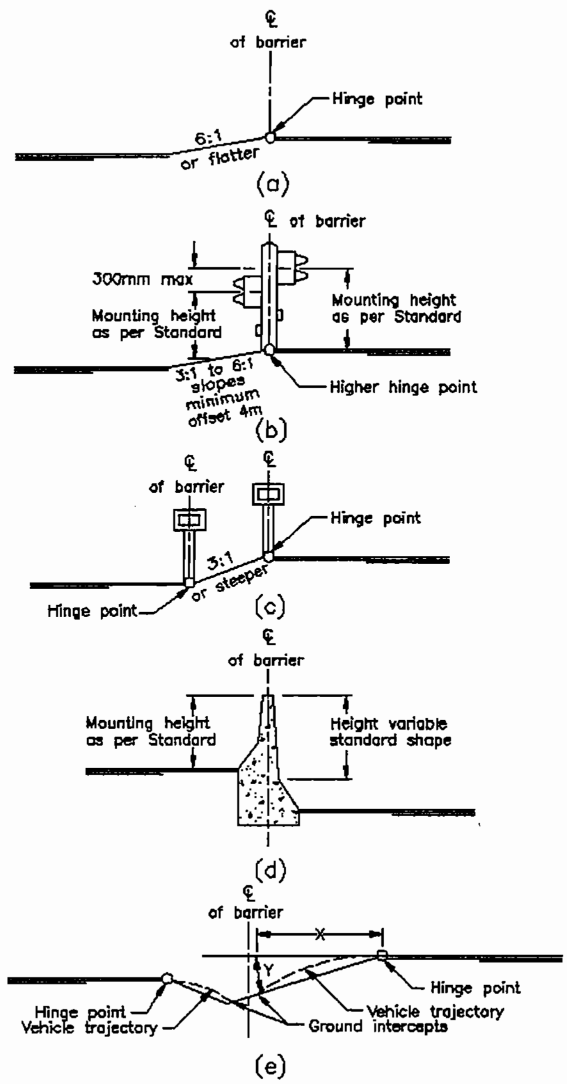


Figure 2.10.3 Placement of Guide Rail on Stepped Medians

EXAMPLE

Speed of vehicle leaving the roadway is 100 km/h. Slope of shoulder at 6 percent. Side slopes 3:1.

Calculate and plot vehicle trajectory at 0.50 m intervals from edge of shoulder.

Since speed		= 100 km/h
K		= .0743 (from table)
s		= .06
Y at 0.5m		$= sx + Kx^2$
		$= (.06 \times .50) + (.0743 \times .50^2)$
		= .049 m
	1.00	= .134
	1.50	= .257
	2.00	= .417
	2.50	= .614
	3.00	= .849
	3.50	= 1.120
	4.00	= 1.429
	4.50	= 1.775

The result of each calculation is now plotted from a base line which is an extension of the shoulder cross fall. See Figure 2.10.4

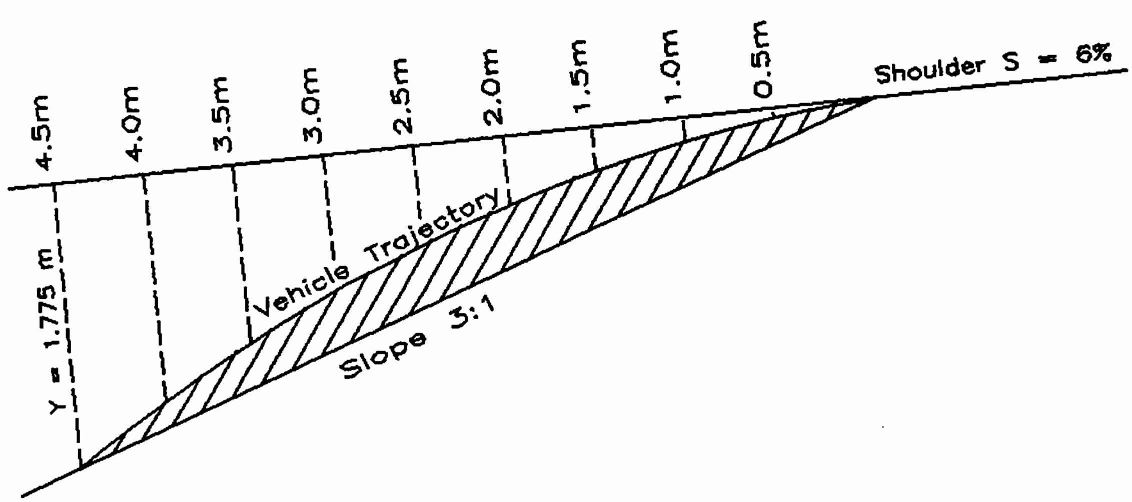


Figure 2.10.4 Vehicle Trajectory

2.10.5 MEDIAN CROSSINGS

POLICY

UNPROTECTED MEDIANS

MEDIAN CROSSINGS ARE DISCOURAGED. However, if alternatives are not feasible, the OPS standard drawing for crossings, including deceleration tapers must be strictly adhered to. The location of the proposed crossing must be chosen to ensure maximum visibility. The deceleration tapers are not to be paved. Existing median crossovers should be removed wherever possible during resurfacing or reconstruction projects.

PROTECTED MEDIANS

OPENINGS IN MEDIAN BARRIERS FOR EMERGENCY OR OTHER PURPOSES ARE NOT ALLOWED.

Vehicles decelerating and accelerating in the high speed lanes, manoeuvring in the opening, and entering, possibly blindly, into the high speed lanes is unacceptable. The risk of openings in medians to the travelling public is far greater than the potential benefits to emergency crews or accident victims.

2.10.6 MEDIAN STOPPING SIGHT DISTANCE

GUIDELINE

The designer must check at all horizontal curves to ensure that there is sufficient stopping sight distance, particularly in the fast or inside lane. The Tall Wall barrier, IBC, and possibly Steel Beam barrier systems are high enough that vehicles parked on the median shoulder may not be visible with sufficient warning. Refer to the Geometric Design Manual to determine the minimum stopping sight distance required. When stopping sight distance is substandard, the shoulder may be widened, or the barrier shifted from the centre line.

2.10.7 MEDIAN SIGN SUPPORTS

GUIDELINE

All signs must conform to the MUTCD Manual and the Sign Support Manual. Refer also to Chapter 6, for additional information on sign supports. The supports must either be contained within the guide rail system to prevent snagging, or be mounted on top of the barrier. The material should bend, not snap off, to ensure that the supports or signs do not become projectiles. For appropriate designs contact the Maintenance Operations Office. Consideration should also be given to the possibility of vehicles such as trucks or buses driving on the adjacent shoulders. The lean of these vehicles may be sufficient to cause them to strike the sign.

2.10.8 GLARE

POLICY

IT IS MINISTRY POLICY TO PROVIDE ANTI-GLARE SCREENS ON A SITE SPECIFIC BASIS WHERE IT HAS BEEN DETERMINED THAT THERE IS AN OPERATIONAL PROBLEM, AND WHERE IT CAN BE DEMONSTRATED TO BE COST-EFFECTIVE. THIS IS TO BE DETERMINED BY THE REGIONAL TRAFFIC SECTIONS.

2.11 HIGH MAST LIGHTING, FTMS, AND OVERHEAD TRUSSES

Note: FTMS = Freeway Traffic Management System (Changeable message signs)

Due to the massive design and high cost of these structures, and the severe consequences of being struck, special protection is warranted.

For additional information regarding High Mast Lighting refer to Chapter 6.

POLICY

WHEN HIGH MAST LIGHTING, FTMS AND OTHER OVERHEAD SIGNS ARE PLACED WITHIN THE CLEAR ZONE, (CHAPTER 2.0, SECTION 2.3) THEY MUST BE EITHER;

> MOUNTED ON SPECIALLY DESIGNED FOOTINGS, 1050 MM HIGH, TRANSITIONED TO THE APPROPRIATE BARRIER SYSTEM, WITH THE BARRIER WIDENED AT EACH LOCATION (REFER TO THE APPLICABLE STANDARD DRAWINGS IN THE OPSD MANUAL.);
> **OR**
> PREFERABLY, BE LOCATED BEYOND THE DEFLECTION DISTANCE OF THE BARRIER THAT PROVIDES PROTECTION.

If mounted on concrete barrier the minimum offset from the toe of the barrier to the face of the sign support or pole shall be the minimum offset shown on the OPS drawings for highmast, or 450 mm measured at a height of 4.2 m above the pavement surface. This is to prevent trucks or buses that are driving or parked on the shoulder from coming in contact with the sign support or pole.

For information on other illumination or sign support standards, refer to Chapter 6.0, the Ontario Highway Bridge Design Code, and the Ministry Sign Support Manual.

2.12 CONSTRUCTION ZONES

Posted or advisory speeds in construction zones may be lower than on through roadways. Even though the motorists are apt to be more cautious and or alert, protection is still required. The level of protection required, either barriers or delineation, is to be determined on a site specific basis, by design, traffic, and construction staff.

The contract package should include the appropriate protection required for staging of the project and anticipated method of construction. Construction and traffic staff should be consulted on the staging and protection schemes. **When the Contractor wishes to deviate from the staging plan for the project, the proposed alternative must comply with policies contained in this manual.**

2.12.1 PRECAST BARRIERS

Precast concrete barriers (refer also to Chapter 4, Section 4.2.7) are usually introduced in construction zones where a higher level of protection is required during construction. They also may be used as permanent barriers where cost effective. When used for this purpose, the connections are galvanized. The precast barriers must not be used as a permanent installation where a high performance barrier is required.

The application of precast barriers is dependent on the judgement of the designer in consultation with traffic and construction staff. Precast concrete barriers are typically used whenever protection of a temporary nature is required to:

- separate opposing traffic in freeway work zones;
- protect temporary facilities such as falsework from traffic;
- provide protection when the combination of duration of the operation, offset from traffic, traffic speed and volume pose an unreasonable risk; and
- channelize traffic on high speed facilities where the change in alignment or lane width is out of character with the facility.

Precast barriers should not be used in isolation. Rather, they should be used in conjunction with delineators well in advance of the installation as indicated in the MUTCD Manual.

POLICY

WHERE PROTECTION IS PROVIDED BY A PRECAST BARRIER SYSTEM, STANDARD SYSTEMS MUST BE USED AND THE ENDS OF THE SYSTEM MUST BE PROTECTED.

Planning and design should be consulted for all but minor modification made in the field.

END TREATMENTS AND TRANSITIONS - Refer also to Chapter 4, Section 4.2.7

The approach ends of temporary barrier shall be either

- connected to an existing permanent barrier, or
- installed so that the entire turned down portion of the flared treatment is located beyond the clear zone offsets shown in Table 2.2.1, Chapter 2.2, or
- where the temporary concrete barrier installation end is straight (parallel with traffic) or only partially flared, the turned down units shall not be used. The exposed end shall be attached to or shielded by an approved end treatment or crash cushion, typically the temporary GREAT or CAT for narrow, and CIAS for wider hazards. Both GREAT and CIAS are ideally suited for situations where staging demands relocation of the attenuating device. CAT is the recommended treatment for locations that require protection for the duration of the contract. Sand filled energy absorption modules should not be used to shield the ends of temporary barriers on facilities posted at 80 km/h or greater. They may be used when other devices can not be accommodated due to site or schedule restrictions.

The leaving end on undivided highways is to be treated in the same way as the approach end, with the clear zone offset measured from the centreline of the roadway. The leaving end need not be shielded on divided freeways where there is no opportunity for impact (typically where shielded by a median barrier). The trailing end of a barrier if located near a rigid obstacle (retaining wall, bridge abutment etc.), should be extended at full height and connected to, or overlap the obstacle.

PROCEDURE

The length of the installation shall be based on the design speed of the detour or in the case of no detour the design speed of the highway. When calculating the length, the energy attenuator or end treatment is not included, but the flared portion of the barrier may be included in the length of need.

Where the appropriate offset, length or flare cannot be applied it is preferable to compromise on the flare rate of barriers or length of need rather than on clear zone offset. Deviations from the clear zone commensurate with exposure and potential severity of accidents shall be justified and documented in the "Design Synopsis" in the design stage, or in the contract administrator's diary, if modifications are made during construction.

For lane and shoulder closures the barrier is not to be used in isolation. Rather it shall be used in conjunction with approved traffic delineation devices and signs to channel traffic, as indicated in the MUTCD.

Temporary concrete barrier installations shall be connected to permanent barriers or structures where feasible. The ends shall be placed so that they do not pose a hazard to the motorist.

ACCESS

When access is required for construction equipment, the designer should allow, when feasible, access at the leaving end of the barrier relative to adjacent traffic whenever possible. The end shall be flared as much as possible while still allowing access. However, if it is not flared beyond the clear zone offset relative to oncoming traffic, the end must be protected by an energy attenuating device, and delineated as per the MUTCD manual. The access openings in a continuous temporary barrier shall be treated as ends.

MOUNTING HEIGHT

If steel beam or cable systems are installed before the final installation of the shoulders, the beam or cable shall be mounted at the correct height relative to the grade. Upon completion of the project, the guide rail must then be adjusted to suit the final elevation. These situations will typically occur during seasonal or winter shutdown, and should be specified in the contract documents.

OFFSET

Temporary concrete barrier installations should be installed with a minimum offset of 1.0 m from structures not designed for impacts (ie. scaffolding), or be adequately restrained to prevent deflection. When precast barriers are used to protect excavations, a 0.5 m offset should be used. When the 0.5 m offset from a drop-off cannot be achieved, the units need not be restrained provided the traffic lane is within 1 metre of the toe of the barrier and the units are placed as tightly together as possible to minimize deflection.

LANE REDUCTION

The designer should consider the effect of using precast concrete barrier on both sides of a traffic lane, since some large farm equipment may not be able to negotiate the reduced lane widths. This problem is prevalent on structure rehabilitation projects, where a portion of the structure is closed, and the precast concrete barriers are used to protect the workmen. Placement of the barriers should take the above into account where there is evidence that problems may occur.

GLARE

The glare screens in construction zones are treated in the same manner as on permanent facilities. Refer to Section 3.4.3.

VISIBILITY

Temporary concrete barriers placed on curved alignments should be located to provide the minimum stopping sight distance corresponding to the construction zone design speed. Planning and Design should be consulted when modifications are made in the field.

DRAINAGE

The openings in the underside of the temporary barriers provided for lifting devices, must be kept clear of debris to provide free passage of storm water run off.

2.12.2 DELINEATION

Protection for hazards created by contactor operations is described in the Manual of Uniform Traffic Devices (MUTCD) and in the contract documentation. Staff should note that delineators such as TC 54's specified in the MUTCD manual are not considered to be barriers and should not be used as such.

2.12.3 EXAMPLE OF DETOUR CONFIGURATION

To avoid end treatments for temporary concrete barrier installations, the designer may be able to make use of existing guide rail systems as illustrated in Figures 2.12.1 and 2.12.2. In the former, the two approach end treatments are shown, one utilizing an energy attenuation system, and the other has been flared away from approaching traffic. Since the existing cable guide rail system has a 3 m deflection, the approach end treatment must be offset a distance equal to or greater than this deflection. A minimum overlap of the two systems is required to ensure continuity in protection and maximum strength at the initial point of overlap. The same design approach is used in Figure 2.12.2 when the barriers are placed for winter shut down. Both ends are flared away from approaching traffic, with a minimum 3 metre offset to allow for deflection of the existing cable system.

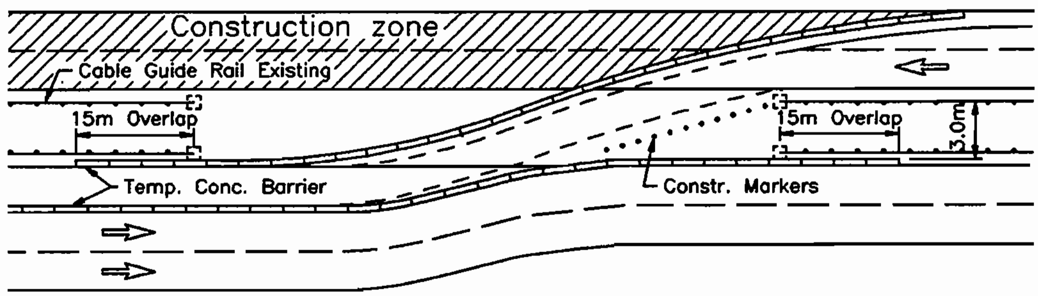


Figure 2.12.1 Detour Open

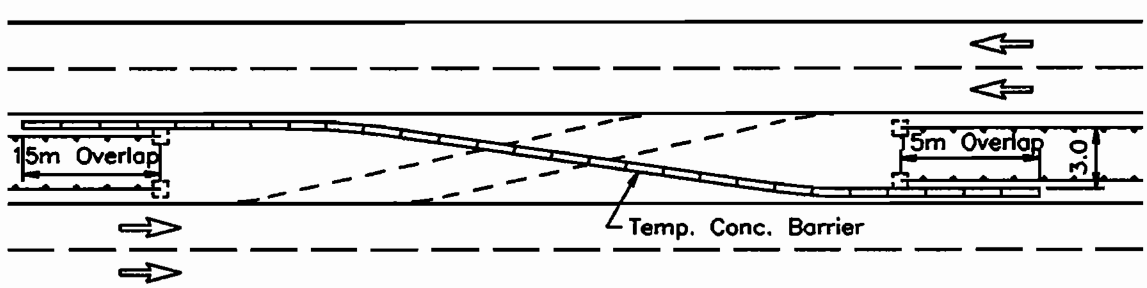


Figure 2.12.2 Detour Closed

2.13 BARRIER SELECTION IN AN URBAN ENVIRONMENT

On high speed, high volume freeways which are generally found in urban areas, maintenance operations to repair damaged guide rail can contribute to significant delays in the normal operation of the roadway. In addition to delaying traffic, the maintenance function introduces a hazard, both to the motorist and the maintenance worker. Since concrete barrier has proven to be the most maintenance free system, the following policy will apply on freeways within an urban environment.

POLICY

ON ALL FREEWAYS IN AN URBAN ENVIRONMENT, ALL BARRIERS PLACED ON THE SHOULDER SHALL BE CONCRETE BARRIERS WITH THE EXCEPTION OF BARRIERS PLACED BEYOND THE SHOULDER.

ALL BARRIERS ON ARTERIAL ROADS THAT CROSS FREEWAYS IN AN "URBAN ENVIRONMENT" AND WHICH ARE A CONTINUATION OF CONCRETE BARRIERS ON RAMPS AND LOOPS, AND ANY OTHER WARRANTED BARRIERS ON THE ARTERIAL ROAD WITHIN THE INTERCHANGE AREA, SHALL BE CONCRETE. THE BARRIER TYPE OUTSIDE THE INTERCHANGE AREA, (IE. BEYOND THE OUTER BULL NOSES) SHALL BE AT THE DISCRETION OF THE DESIGNER. REFER ALSO TO CHAPTER 3.0

ALL FREEWAY TO FREEWAY INTERCHANGE RAMPS, WHETHER IN AN URBAN OR RURAL ENVIRONMENT, SHALL USE CONCRETE BARRIER SYSTEMS WHERE SHIELDING IS REQUIRED. REFER ALSO TO CHAPTER 2.0, SECTION 2.9.4.

Freeways in an urban environment would normally have the following characteristics:

- 10 year projected AADT greater than 75,000
- 6 lanes or more
- multiple interchanges spaced 1 to 2 kilometres apart
- freeway to freeway interchanges
- urban drainage
- complex signing requirements including FTMS
- illumination, and
- a significant requirement for protection other than for medians.

2.14 COST ANALYSIS

OVERVIEW

Sometimes, more than one guide rail system, end treatment, or energy attenuator is suitable for use at a given location. The procedures for comparing alternatives outlined in this chapter are intended to help the designer select the appropriate alternative, based on cost alone. It cannot be too strongly emphasized, however, that no economic evaluation can replace the sound judgement of experienced designers, which also take into account safety, performance, environmental effects, construction restrictions, and aesthetics. Such factors are relevant and often determine the alternative that is selected.

POLICY

IF TWO OR MORE GUIDE RAIL SYSTEMS, END TREATMENTS, OR ENERGY ATTENUATORS ARE FOUND TO BE SUITABLE AT A GIVEN LOCATION, THE SELECTION WILL BE BASED ON A LIFE CYCLE ANALYSIS AND BENEFIT COST.

The designer should consider not only the initial installation costs, but also ongoing maintenance considerations over a minimum 30 year life span, as well as benefits or costs to society as a whole.

2.14.1 LIFE CYCLE COST

OVERVIEW

The life cycle cost of an item is the sum of all the expenditures associated with the item during its entire service life. For the purpose of economic comparison of alternative barrier systems, the designer should consider:

- capital cost,
- operating and maintenance cost, and
- removal cost.

The capital cost is the total investment required to get the barrier ready for service. This includes not only the purchase price, but also the total installation cost, which will include shoulder paving and the drainage installations required to ensure the proper operation of the barrier, (ie. activities that would not take place otherwise).

Operating and maintenance costs are the recurring costs of operating and maintaining the system during its useful life. The ministry practises maintenance on an as needed basis. The designer should contact Regional maintenance staff to determine the estimated maintenance costs for each type of system being compared.

When the projected life cycle of a barrier system is less then the standard 30 year life cycle, the removal costs should be included in the analysis.

METHOD

Designers shall use the following generic procedures when comparing barrier alternatives. All the steps may not be appropriate for all cases.

1) Define the set of alternatives to be compared.
2) Define the planning period to be used in the analysis.
3) Develop the cash flows to be used.
4) Specify the time value of money to be used.
5) Specify the method of selection.
6) Compare the alternatives.
7) Select the preferred alternative.

EXAMPLE 2.14.1

The following example illustrates the method used to select the appropriate system, based on financial considerations. Other considerations may well apply. However, only costs are considered in this example.

The quantities and costs used in this example are for illustration only and should not be used as models or standards by the designer. Cost estimates should be obtained from the Estimating Office, and quantities should be derived by the designers, specific to their application.

Given:

- Existing 4 lane freeway, 14.5 metre median
- Design speed, 120 km/h
- Operational problem identified
- Approval for median barrier received
- Projected requirement for 6 lanes in 15 years

Barrier Options:

- 6 cable/steel posts
- IBC MK7 barrier
- Concrete barrier

Potential application Options

1) Do nothing - This is always a valid option and should be considered, particularly in cost/benefit analysis
2) install 6 cable now, concrete in 15 years
3) install 6 cable now, IBC MK7 in 15 years
4) install IBC MK7 now, concrete in 15 years
5) install IBC MK7 now, reconstruct IBC MK7 in 15 years
6) build 6 lanes now, with concrete barrier (Option 6 is not considered for this example, however it may well be a valid alternative).

Concrete barrier now was not chosen as an option since it would result in a paved shoulder width of approximately 7 metres which is excessive.

Costs for the above options are calculated based on a 1 kilometre length. Discount rate used to calculate present values is 10 percent.

OPTION 1 - (do nothing) Cost of option 1 = $0

OPTION 2 - (install 6 cable now, replace with concrete in 15 years)

YEAR 1 TO YEAR 15

	quantity	cost	present value
6 cable guide rail (m)	1,000	45,000	45,000
Granular A (tonne)	15,168	151,680	151,680
Stripping (cubic metre)	840	8,400	8,400
Surface Treatment (sq m)	15,200	30,400	30,400
Adjust/rebuild CB's (each)	10	400	4,000
Breaking into CB's (each)	10	300	3,000
Pipe subdrain (m)	1,000	20,000	20,000
Maintenance (km/year) 15 years		366	2,784(1)
		SUBTOTAL	265,264

YEAR 15 TO YEAR 30

	quantity	cost	present value
Removal 6 cable guide rail (m)	1,000	4,000	958(2)
Removal anchor blocks (each)	6	600	144
Storm Sewer (m)	1,000	200,000	47,880
Gran A (tonne)	2,246	22,460	5,377
Hot mix new lane (t)	12,326	116,300	27,842
Hot mix paved shoulder (t)	683	34,150	8,176
Concrete barrier	1,000	85,000	20,349
Maintenance (km/year) 15 years		223	406(3)
		SUBTOTAL	111,131

TOTAL OPTION 2 YEAR 1 TO YEAR 30 376,395

(1) P = A(P/A i,n) Note: formulas and values can be obtained from Tables in most Economic Analysis Texts
(2) P = F(P/F i,n)
(3) P = A(P/A i,n)(P/F i,n)

OPTION 3 (install 6 cable now, replace with IBC MK7 in 15 years)

YEAR 1 TO YEAR 15 (See option 1)			
		SUBTOTAL	265,264
YEAR 15 TO 30			
Removal 6 cable guide rail (m)	1,000	4,000	958
Removal anchor blocks (each)	6	600	144
Storm Sewer (m)	1,000	200,000	47,880
Gran A (tonne)	2,246	22,460	5,377
Hot mix new lane (t)	2,326	116,300	27,842
Hot mix paved shoulder (t)	683	34,150	8,176
IBC MK7 Barrier (m)	1,000	275,000	65,835
Maintenance (km/year) 15 years		1,500	2,731
		SUBTOTAL	158,943
TOTAL OPTION 3 YEAR 1 TO YEAR 30			424,207

OPTION 4 (install IBC MK7 now, replace with concrete in 15 years)

YEAR 1 TO YEAR 15	quantity	cost	present value
IBC MK7 barrier (m)	1,000	275,000	275,000
Granular A (tonne)	18,336	183,360	183,360
Stripping (cubic metre)	840	8,400	8,400
Surface Treatment (sq m)	14,200	28,400	28,400
Adjust/rebuild CB's (each)	10	400	4,000
Breaking into CB's (each)	10	300	3,000
Pipe subdrain (m)	1,000	20,000	20,000
Maintenance (km/year) 15 years		1,500	11,109
		SUBTOTAL	533,269
YEAR 15 TO YEAR 30			
Removal IBC MK7 (m)	1,000	20,000	4,788
Storm Sewer (m)	1,000	200,000	47,880
Gran A (tonne)	500	5,000	1,197
Hot mix new lane (t)	2,326	116,300	27,842
Hot mix paved shoulder (t)	683	34,150	8,176
Concrete barrier	1,000	85,000	20,349
Maintenance (km/yr) 15 years		223	406
		SUBTOTAL	110,638
TOTAL OPTION 4 YEAR 1 TO YEAR 30			643,107

OPTION 5 (install IBC MK7 now, reconstruct IBC MK7 in 15 years)

YEAR 1 TO YEAR 15

	quantity	cost	present value
IBC MK7 barrier (m)	1,000	275,000	275,000
Granular A (tonne)	18,336	183,360	183,360
Stripping (cubic metre)	840	8,400	8,400
Surface Treatment (sq m)	14,200	28,400	28,400
Adjust/rebuild CB's (each)	10	4,000	4,000
Breaking into CB's (each)	10	3,000	3,000
Pipe subdrain (m)	1,000	20,000	20,000
Maintenance (km/year) 15 years		1,500	11,109
		SUBTOTAL	533,269

YEAR 15 TO YEAR 30

	quantity	cost	present value
Reconstruct IBC MK7 (m)	1,000	30,000	7,182
Storm Sewer (m)	1,000	200,000	47,880
Gran A (tonne)	2,246	22,460	5,377
Hot mix new lane (t)	2,326	116,300	27,842
Hot mix paved shoulder (t)	683	34,150	8,176
Maintenance (km/year) 15 years		1,500	2,731
		SUBTOTAL	99,188

TOTAL OPTION 5 YEAR ONE TO YEAR 30 632,457

Selection for this example to be based on least expensive alternative. Option 1, although it has no cost, is not valid for this since an operational problem has been identified.

SUMMARY OF COSTS

OPTION 1, do nothing	$ 0
OPTION 2, install 6 cable now, replace with concrete in 15 years	$ 376,395
OPTION 3, install 6 cable now, replace with IBC MK7 in 15 years	$ 424,207
OPTION 4, install IBC MK7 now, replace with concrete in 15 years	$ 643,107
OPTION 5, install IBC MK7 now, reconstruct IBC MK7 in 5 years	$ 632,457

No consideration was given to the social benefits of the above alternatives. Section 2.14.2 continues the above example, illustrating the use of benefit cost analysis to determine the appropriate alternative.

The example continues in Section 2.14.2, illustrating the Benefit-Cost principle.

2.14.2 BENEFIT-COST

OVERVIEW

The economic and societal cost of even one accident resulting in fatality or severe injury is substantial. It is usually self evident where additional protection at hazards is required. Nevertheless, the designer should be aware of the costs and benefits associated with a given level of protection even though a rigorous cost/benefit analysis may not always be carried out. In examining the costs and benefits of a traffic barrier installation, the benefit to society of protecting the hazard is compared to the total life cycle cost (Section 2.14.1) of providing the protection.

The main benefit of installing a traffic barrier is the expected reduction in future accident costs, including fatal accidents, personal injury accidents and property damage accidents. Designers must be able to estimate the number and severity of future accidents to properly assess their cost. The accident data and projections can normally be obtained from the Regional Traffic Offices.

Estimated values currently used in cost benefit analysis for accidents are as follows:

Fatality	$ 750,000
Severe injury	$ 50,000
Minor injury	$ 10,000
Property damage only	$ 6,000

These figures represent direct societal costs and are not intended to reflect the value of a human life.

In some circumstances, such as the construction of a median barrier, the number of accidents is likely to increase, due to collisions with the barrier. However, the work will lead to a compensating reduction in accident severity, with the virtual elimination of cross median, head-on accidents.

The costs used in a cost/benefit analysis are the direct construction and maintenance costs incurred by the Ministry. Although the initial capital outlay is well defined and easily estimated, the maintenance costs may be less obvious. The frequency of collisions and ease of repair of damaged traffic barriers, must be considered along with the cost of lane closures and delays to the travelling public, particularly on heavily travelled highways. Cable systems are relatively inexpensive to install but sustain major damage in vehicle impacts, and are difficult to repair during the winter. This means that damaged sections might remain inoperable for extended periods. By contrast concrete barriers are more costly to install but need little repair after most accidents.

The analysis should also consider the design life over which the costs and benefits will accrue. As they occur at widely different times, both costs and benefits should be annualized, to allow direct comparison of the alternatives. The annualized benefit/cost ratio thus compares the savings to society (reduced accidents) to the cost of providing the additional protection.

In principle the notion of benefit-cost is relatively simple. It follows the same approach as used in life-cycle costs, but, in addition to installation and maintenance costs, also considers societal costs.

INCREMENTAL BENEFIT-COST

When two or more project alternatives are being compared, using a benefit-cost ratio, the analysis should be done on an incremental basis, to realize the greatest benefit at the least cost. The alternatives should first be ordered from lowest to highest cost. The incremental benefits of the second alternative over the first, are calculated by dividing the incremental costs of the second over the first. If the ratio is greater than 1, then alternative 2 is preferred. If the ratio is less than 1 then alternative 1 is the superior alternative. The better of these is then compared with the next most costly alternative. Comparison of successive pairs are continued until all the alternatives have been considered. Note that if the first alternative is " do nothing," the incremental B/C ratio is also the straight B/C ratio for the second alternative.

Example 2.14.1 cont'd

Accident Data - Figures are per km per year*

	fatals	severe injuries	injuries	property damage only
Existing conditions	0.2	0.8	14	12
6 cable (projected)	0.02	0.08	20	24
Concrete (projected)	0.01	0.06	7	12
IBC MK7 (projected)	0.01	0.06	14	24

* Data is derived solely for this example and should not be used for other purposes.

Benefit installing	6 cable	=	(.2 - .02) 750,000 + (.8 - .08) 50,000 + (14 - 20) 10,000 + (12 - 24) 6,000
		=	39,000
Similarly	Concrete	=	249,500
Similarly	IBC MK7	=	107,500

Present Value of benefit - Option 2

P = A(P/A,10,15) + A(P/A,10,15)(P/F,10,15)
= 39,000 x 7.6061 + 249,500 x 7.6061 x .2394
= 750,952

Similarly present Value of Benefit
Option 3 = 492,385
Option 4 = 1,272,000
Option 5 = 1,013,000

INCREMENTAL BENEFIT/COST ANALYSIS

Rank in order of cost:

	cost	benefit
OPTION 1	$ 0	0
OPTION 2	$ 376,395	751,000
OPTION 3	$ 424,207	492,000
OPTION 5	$ 632,457	1,013,000
OPTION 4	$ 643,107	1,272,000

OPTION 1 VERSUS OPTION 2:

Incremental Benefit = 751,000 - 0 = 751,000
Incremental Cost = 376,395 - 0 = 376,395
Benefit/Cost Option 2 versus 1 = 751,000/376,395 = 2.0 is greater than 1
Therefore Option 2 is preferred over Option 1.

OPTION 2 VERSUS OPTION 3:

Incremental Benefit = 492,000 - 751,000 = - 259,000
Incremental Cost = 424,207 - 376,395 = 47,812
Benefit/Cost Option 3 versus Option 2 = - 259,000/47,812 = - 5.4
Therefore Option 2 is preferred over Option 3

OPTION 5 VERSUS OPTION 2

Incremental Benefit = 1,013,000 - 751,000 = 262,000
Incremental Cost = 632,457 - 376,395 = 256,062
Benefit/Cost Option 5 versus Option 2 = 262,000/258,793 = 1.01
Therefore Option 5 is preferred over Option 2

OPTION 4 VERSUS OPTION 5

Incremental Benefit = 1,272,000 - 1,013,000 = 259,000
Incremental Cost = 643,107 - 632,457 = 10,650
Benefit/Cost Option 5 versus Option 2 = 259,000/10,650 = 24.3
Therefore Option 4 is preferred over Option 5.

Based on the data supplied the benefit cost analysis indicates that option 4 (install IBC MK7 now and replace with concrete barrier in 15 years) is the preferred alternative.

NOTE The above example is based purely on derived data, and is intended for illustrative purposes only. The designer must use data acquired for each specific work project.

DETAILED TABLE OF CONTENT

3.1 CHAPTER OVERVIEW

Once warrants for protection have been established, the designer must select the appropriate type of barrier system. The first consideration is the type of protection required; a longitudinal barrier or crash cushion, and whether it will be a permanent or temporary installation. This chapter considers the selection criteria for permanent installations of longitudinal barriers, both roadside and median, as well as crash cushions and end treatments. For temporary systems, refer to Chapter 2, Section 2.12, and Chapter 5.

The key costs considered when selecting a barrier type are maintenance costs and cost of benefits related to barrier performance. Both costs are directly related to traffic volumes. Since it is not practical to ask the designer to perform a benefit cost analysis routinely, guideline Tables 3.1.1 and 3.1.2 listing the various types of barrier types and the recommended traffic volumes at which they should be used were developed. Other considerations apply, however, and some barriers systems perform relatively poorly in certain locations. For this reason, conditions and restrictions on their usage have been established. Refer to Table 3.1.3, and to the remainder of this chapter for an explanation of these conditions and restriction.

After eliminating some types of barriers based on traffic volumes, the primary considerations in selecting a barrier system are strength, deflection, site conditions, maintenance and cost.

METHOD OF SELECTION

1) Determine appropriate barrier/s based on traffic volumes. Table 3.1.1 Roadside barriers, and Table 3.1.2 Median barriers.
2) Determine from Table 3.1.3 if restrictions apply for the specific application.
3) Review the remainder of this chapter, Section 3.2 Roadside, and Section 3.3 Median, and select based on strength, deflection, site conditions, maintenance, and actual cost.

Strength implies that the barrier must provide adequate protection from the given hazard, considering the design vehicle.

Deflection refers to the maximum anticipated deflection of the system when hit by the design vehicle at the design speed and angle.

Site conditions refer to the geometry of the roadway in the vicinity, and include the roadway cross-section features at the proposed installation.

Maintenance considerations include routine maintenance and repair to the system after a collision. Maintenance considerations should also include potential for traffic disruption, exposure of maintenance staff to traffic, and exposure of motorists to the hazard during repairs.

Cost considerations usually determine the final choice of the barrier. They include acquisition, installation, and related modifications to the roadway cross-section. Choosing between two or more seemingly appropriate systems may justify a close examination of design details, as well as a life cycle and cost benefit analysis. Refer to Chapter 2, Section 2.14.

When selection is completed refer to Chapter 3, Section 3.4.1 and 3.4.2 for calculation or determination of required length.

Note: Tables 3.1.1, 3.1.2 and 3.1.3 are not to be considered as the sole criteria for selection. Refer also to the remainder of this chapter.

Table 3.1.1

Recommended Roadside Barriers for Range of Traffic Volumes

System	*AADT	Note
3 Cable undivided highway undivided highway divided highway	 < 12,000 < 30,000 < 60,000	 2 lane 4 lane
Box Beam undivided highway undivided highway divided highway	 < 15,000 < 30,000 < 60,000	 2 lane 4 lane
Steel Beam undivided highway divided highway	 > 12,000 > 40,000	
IBC Mark 7 undivided highway divided highway	 > 30,000 > 75,000	NOTE 1: These barriers should be used in locations where failure could result in a catastrophe ie. chemical plants, refineries, school yards etc. They should also be used at small radius curves with history of truck overturning.
Standard Concrete undivided highway divided highway	 > 30,000 > 75,000	
Ontario Tall Wall	Note 1	
IBC Mark7HV	Note 1	

* AADT - Average Annual Daily Traffic in both directions.

Table 3.1.2
Recommended Median Barriers for Range of Traffic Volumes

System	AADT	Truck Volume	Note
6 cable/steel post	< 20,000	< 1,500	
Box Beam	< 30,000	< 1,500	posted speed < 80
Steel Beam	> 20,000	< 3,000	
IBC Mark 7 IBC Mark 7HV	> 20,000 > 20,000	< 9,000 > 9,000	
Standard Concrete	> 20,000	< 9,000	
Ontario Tall Wall	> 20,000	> 9,000	not required between core and collectors

POLICY

RESTRICTION SHALL APPLY ON THE SELECTION OF BARRIERS AS SHOWN ON TABLE 3.1.3. (Next Page)

Table 3.1.3 Restrictions on Barrier Usage.

Type	Restrictions
3 cable	- not on urban freeways* - not as median barrier - not on radii less than 250 m - not with curb and gutter any type - not with hazard offset less than 3 m
Box Beam	- not on urban freeways* - not as new median installation on facilities with posted speed greater than 80 km/h - not with barrier or semi-mountable curb and gutter - not on radii less than 600 m
6 cable/steel posts	- not on urban freeways* - not with curb and gutter any type - not on radii less than 600 m
Steel Beam	- not on urban freeways* - not on freeway medians with truck volumes greater than 3000 per day
Standard Concrete Barrier	- not on medians with truck volumes greater than 9,000 - not with curb and gutter any type
IBC MK-7	- not on shoulders less than 3 m width - not with stepped medians - not with truck volumes greater than 9,000 per day - not with curb and gutter any type
IBC MK-7HV	- not on shoulders less than 3 m width - not with stepped medians - not with curb and gutter any type
Ontario Tall Wall	- not with curb and gutter any type

* Refers to shoulder installations. See Chapter 2, Section 2.13

3.2 ROADSIDE BARRIER SELECTION

Refer also to Section 3.1, Tables 3.1.1, and 3.1.3.

3.2.1 STRENGTH

The first decision to be made when selecting a roadside barrier is determining the level of service that is required. Longitudinal barriers function primarily by redirecting and containing errant vehicles. Along the roadside, they are normally intended to protect traffic from obstacles or embankment slopes. All barriers are designed to perform satisfactorily for the range of design vehicles and conditions, but some barriers exceed the design requirements. Because of their higher costs they are recommended for locations with higher volumes of traffic, or locations that experience frequent accidents.

If the protection of passenger car vehicles is the main concern any of the standard barrier systems may be used, taking into account Tables 3.1.1, and 3.1.3. On low volume, low commercial vehicle volume facilities, a cable or box beam system is adequate. For high volume facilities with larger numbers of trucks, steel beam, IBC MK7, or concrete are more appropriate. For high volume facilities with a very large number of trucks, and in areas such as school yards, fairgrounds, or storage locations for chemicals or flammable fuels adjacent to the roadway, where the consequences of penetration by an errant vehicle would be catastrophic, or accidents involving trucks are likely, the use of a high performance barrier is recommended. Refer to Chapter 2, Section 2.10.2 for high performance barrier warrants. If a high performance barrier is warranted, only the IBC MK-7HV or the Ontario Tall Wall have been approved for use on provincial highways.

A barrier must be long enough or adequately anchored to develop its full strength. The designer should be familiar with this concept and make the appropriate selection to fit the specific site. Refer to Chapter 3, Section 3.4.

3.2.2 DEFLECTION

Once the strength requirements of the roadside barrier have been determined, deflection must be considered. Deflection is the offset distance that the barrier is expected to deflect, measured from the front face of the barrier. If the distance between the proposed barrier and the object or feature to be shielded is relatively large a semi rigid system such as steel beam barrier, which deflects upon impact, or more flexible systems, such as cable or box beam, may be a better choice than concrete. The energy dissipated by the deflection of the barrier, particularly the steel beam system, will result in less force being imposed on the vehicle and its occupants, perhaps resulting in less severe vehicular damage and personal injury. This assumes, of course, that the systems, and particularly the cable and box beam, are installed and maintained properly.

If the hazard is immediately adjacent to the barrier and large deflections cannot be tolerated, a semi-rigid barrier, such as steel beam, IBC MK7, or a rigid concrete barrier may be the only appropriate choice. The deflection of the steel beam or box beam system can be reduced by decreasing the standard post spacing, or adding additional beam elements or channel. This is done at connections to fixed rigid objects, or at isolated fixed objects located within the deflection range of the proposed guide rail system. The designer should refer to the deflection characteristics of the various barrier systems contained in Chapter 4.0, and summarized in Table 3.2.1.

Table 3.2.1

Summary of Deflection Characteristics for Roadside Barriers

Guide rail	Deflection
3 Cable	up to 3 m
Box Beam with Double Beam	up to 1.5 m up to 0.6 m
Steel Beam with Channel	up to 0.9 m up to 0.5 m
IBC MK7	up to 0.5 m
Standard Concrete	0 m

3.2.3 SITE CONDITIONS

Choosing an appropriate barrier is influenced by the geometry of the roadway, the roadway cross-section, and local conditions at the site.

HORIZONTAL ALIGNMENT

Horizontal curvature has a pronounced affect on the performance of cable and box beam barrier systems. **Cable is restricted to a curvature of 250 metre radius or greater, and the box beam system may only be installed on a radius of 180 metres or greater.**

BARRIER CONTINUITY

To minimize the number of end treatments, short gaps between installations should be eliminated. **Where the distance between the end of one installation and the beginning of another is approximately 50 m or less, a continuous guide rail system should be placed.** Closing larger gaps between installations should always be considered by the designer.

OFFSET

The offset from the edge of the roadway to the location of the proposed barrier may also influence the choice of barrier. Increasing the offset may allow an errant vehicle to strike the barrier at a much greater angle. However, it also provides greater recovery space. For this reason it is desirable to offset the barrier as far from the roadway as possible. Some restrictions do apply (refer to Chapter 3, Section 3.4.3). Systems other than concrete should be used if the offset to the barrier location is greater than 4.0 metres. To operate effectively, concrete barriers require a paved surface in front of the barrier, and at offsets greater than 4 metres, the cost of the asphalt/concrete becomes a factor. The paved surface also looks like a driving lane, which may confuse some motorists.

Traditionally barrier systems have been installed at the edge of the shoulder. But it is acceptable and even preferred, to install less rigid systems, such as box beam, cable, steel beam, or IBC as far from the roadway as possible. The designer should ensure that the deflection offset is maintained from the hazard and that the approach slope and surface are suitable. For additional information on the location of guide rails, refer to Chapter 3, Section 3.4.3.

CROSS-SECTION

Irregularities in the approach to guide rails can affect the behaviour of the errant vehicle, and result in unpredictable guide rail performance. For this reason, the only guide rail systems which may be used adjacent to curb and gutter are the steel beam with channel, and the box beam only in conjunction with mountable curb and gutter. Refer to Section 2.7.3, Table 2.7.1 and Figure 2.7.1

Approach surfaces adjacent to concrete barrier must be paved, with a cross slope no greater than 10:1.

For all systems the cross section must ensure adequate lateral support.

3.2.4 MAINTENANCE

Before selecting the barrier, the designer should consider maintenance. It is strongly recommended that the designers seek the advice of the district maintenance staff in the respective regions in this regard.

Maintenance factors to consider in the selection of a barrier system are;

a) repair of damaged sections after an impact;

b) routine maintenance due to deterioration or weathering;

c) the effect of the presence of the barrier on the cost of road and roadside maintenance; and

d) traffic volumes and resulting exposure which have a large impact on maintenance costs.

For example, the proven higher maintenance costs of cable systems may well make them more expensive in the long run, despite their lower initial installation costs. This is particularly true in areas of high traffic volumes, and where cable systems are susceptible to extensive damage during the snow plowing operations.

The following is intended as information for the designer, pointing out maintenance difficulties which may be experienced with the various systems. Refer to the ministry Maintenance Manual, Operating Instructions, Volume IV for specific maintenance details.

CABLE

Maintaining proper tension and mounting height, require a considerable maintenance effort. Cable barriers require post replacement and re-tensioning after an impact. Material costs are low, but the barrier must be serviced after every impact and tension on all installations should be checked periodically.

Due to the narrow target area of the cable system (approximately 75 mm), mounting height is critical. Guide rail posts are susceptible to frost heave, thereby increasing the mounting height of the cable. Proper grading of gravel shoulders is necessary. It ensures that buildup does not occur at the posts or along the face of the guide rail, restricting roadside drainage, and that the gravel is not washed away from under the system. Improper mounting height will also result in under or over ride.

On narrow shoulders, snow accumulation and the plowing operation often break or push posts out of the vertical. Grass cutting around barrier posts may also increase roadside maintenance costs, due to the extra time and effort required.

Cable systems placed in high volume, high accident situations may require considerable maintenance, making this system an impractical choice for these conditions. Collision damage, even for minor impacts, usually requires immediate repairs due to the resulting substandard mounting heights and tension. Proper anchorage is critical to the operation of the system and must be maintained. Post replacement is impractical during the winter months. Missing or broken posts will increase the deflection characteristics, and also result in substandard mounting heights.

BOX BEAM

Proper grading of gravel shoulders is necessary, since it ensures that buildup does not occur at the posts or along the face of the guide rail restricting roadside drainage, or adversely affecting the proper mounting height. Improper mounting height can also result in over or under ride of the system.

The lifting equipment to replace damaged rail sections on box beam barriers increases repair costs, sometimes significantly. Just as for cable, box beam requires attention, as soon as possible even after minor collisions, to ensure proper operation of the system. Since proper connection of the beam elements is critical to strength and the proper operation of the system, the condition of the splice plates, bolts, and paddle slots require inspection periodically.

Post replacement is impossible during the winter months. Temporary prop-legs should be used in the interim to support the beam at the proper mounting height. While these do represent a hazard when struck, the use of these legs is less hazardous than leaving the beam unsupported. Grass cutting around barrier posts may also increase roadside maintenance costs due to the extra effort required.

STEEL BEAM

Because of its relatively wide target area, this system is not as sensitive to mounting height as cable and box beam systems.

To repair steel beam barriers, the beam sections may have to be replaced, but the extent of damage is usually less than for cable, especially if a channel is used. Except in the case of major collisions, the steel beam system remains operational after impact. When it is necessary to replace the beam elements, it is important to ensure that they be overlapped in the direction of traffic, to reduce opportunity for snagging.

Unlike the cable and box beam systems, the posts in steel beam systems, provide lateral resistance. This means that broken or rotted posts must be replaced, and that blocks used to offset the rail should be checked periodically, to guard against splitting and subsequent loss of the block.

IBC

IBC barriers require extensive, (and expensive) repair after impact, factors that may offset the benefits of their large target area and increased strength. Except in a major collision, the damage sustained by an IBC barrier during impact does not require immediate repair to remain fully operational. Protruding panels or lids should be bolted or replaced to avoid vehicle snagging, and the panels must always be overlapped in the direction of traffic.

Repairs to the IBC barriers require specialized equipment, which contributes to the systems high maintenance costs.

Since the sides of the barrier are wider than the base, removal of roadside debris is difficult. Drainage openings in the side of the barrier have a tendency to collect debris, and snow plow operations may plug the drainage openings, which can lead to icing or flooding problems.

CONCRETE

Concrete barriers usually require little or no maintenance after an impact. If damaged, however, the repair costs can be high. As a temporary solution to breakouts, a steel beam element may be bolted to both sides of the opening. To date there have been no recorded instances of breakouts on the wider "C" type barrier and the Ontario Tall Wall. However, on rare occasions, the "A" type barrier has been penetrated.

GENERAL

Snow removal costs may increase with the presence of barriers. Depending on the direction of the prevailing wings the extent of drifting, can increase with decreased post spacing, or with the use of concrete and IBC barriers. Maintenance experience with concrete barriers on north - south routes demonstrate that although increased drifting has occurred, it has not been a significant problem.

Snow and ice accumulation in front of, and on the approaches to, all barriers reduces the effectiveness of the barrier, and in extreme cases may result in vaulting over the system. As weather and resources permit, these accumulations should therefore be removed.

3.2.5 COST

The relative installed costs of the various barrier systems differ considerably, depending on geographic location. The cost of material may depend on availability and economies of scale. In general, however, cable barrier is considerably less expensive than the other systems, and is therefore frequently used where large deflections can be tolerated. Steel beam and concrete systems are competitive with each other, while Box beam and IBC systems are considerably more costly.

The precast concrete barrier while typically more expensive than standard slipformed concrete barrier, may be effectively used where scale of operation or climatic conditions preclude slipforming.

The designer should use the latest figures available from the Estimating Office, to determine the costs of the various alternatives. Total costs, including shoulder treatments and drainage requirements, must be included in all calculations. In addition to the initial installation costs, the cost of maintaining the systems should also be considered.

3.3 MEDIAN BARRIER SELECTION

Refer also to Chapter 3, Section 3.1.

3.3.1 STRENGTH

The first decision a designer makes when selecting a median barrier is determining the level of service required. Longitudinal barriers function primarily by redirecting and containing errant vehicles, and are primarily used to prevent vehicles from crossing the median and entering the opposing traffic stream. All barriers are designed to perform satisfactorily for the range of design vehicles, with some exceeding the minimum requirements. Due to their higher installation costs, barriers that exceed the minimum requirements are recommended only for locations with higher volumes of traffic, or locations that experience frequent accidents.

If passenger vehicle protection is the main concern, then any one of the 6 cable, box beam, steel beam, IBC MK-7, or standard concrete barrier systems may be used, taking into account Tables 3.1.2 and 3.1.3 of Section 3.1.

The wider, "C" type standard concrete barrier has been designed principally to accommodate conventional lighting. Due to its superior strength, however, (no breakouts to date) it may be effectively used at higher truck volume locations where a high performance barrier is not warranted.

Any existing installation of Box Beam less than 0.5 km in length that requires that removal due to a reconstruction project should be re-installed, lengths greater than 0.5 km should be replaced.

Areas which have significant volumes of heavy vehicles require the use of a high performance barrier. Refer to Chapter 2, Section 2.10, for high performance barrier warrants. If a high performance barrier is warranted, only the IBC MK-7HV and the Ontario Tall Wall have been approved for use on provincial highways.

3.3.2 DEFLECTION

Once the strength requirements of the median barrier have been determined, deflection must be considered. Relatively wide, flat medians are suitable for flexible or semi-rigid barriers, provided that the maximum deflection of the system is less than one half of the median width. Narrow medians with high volume, high speed traffic require the use of a rigid barrier system. Refer to Section 3.3.3 for guidance in selection based on median width.

Table 3.3.1

Summary of Deflection Characteristics of Median Barriers

Guide Rail	Deflection
6 cable, Wood Posts	up to 2.5 m
6 Cable, Steel Posts	up to 2.5 m
Box Beam Double Box Beam	up to 1.5 m up to 0.5 m
Steel Beam With Channel	up to 0.9 m up to 0.3 m
Standard Concrete	0 m
IBC MK7	up to 0.5 m
IBC MK7 HV	up to 0.2 m
Ontario Tall Wall	0 m

3.3.3 GEOMETRIC CRITERIA

The choice of median barrier will be influenced by the alignment of the median, both horizontal and vertical, the median cross-section, and local features at the site.

MEDIAN ALIGNMENT

Horizontal

Horizontal curvature has a pronounced effect on both 6 cable and box beam systems. Since these two systems do not perform well on curves, losing their tension or pulling off of the posts, they are restricted to sites which have a minimum radius of 600 metres.

As stated previously, box beam system must not be used as a new installation on highways with a posted speed of 80 km/h or more.

On the inside of curves, solid barrier systems (ie. Concrete, Steel Beam, or IBC) may limit the stopping sight distance. The designer shall check to ensure that the minimum stopping sight distance is maintained at all locations. This may require modifications to the shoulder widths, or offsetting the barrier.

Vertical

The six cable system on steel posts and box beam barrier systems should not be installed on sag vertical curves with a K factor of less than 15. With a K factor of less than 15 the cable spacer may be forced out of the top of the steel posts, or paddles may be forced from the box beam slots on impact, releasing all tension and creating the potential for under-ride.

MEDIAN WIDTH

Median width is a major determinant in the selection of a median barrier. Since more than 50% of vehicles that leave the roadway travel at least 3.0 m from the edge of driving lane, barriers placed in narrow medians will be subjected to a large number of low angle, high speed impacts. It is therefore desirable to construct concrete barrier in narrow medians, (less than 7 m) as it performs best at low angle, high speed impacts and requires a minimal amount of maintenance.

Since barriers perform differently, and based on their total cost differential, it is desirable to restrict barrier types to specific median widths. The following general guideline should be used in median barrier selection.

Table 3.3.2 Barrier Type as a Function of Median Width

Median Width	Barrier Type
Less than 7 m	Concrete
7 to 9 m	Concrete, I.B.C., Steel Beam, or Box Beam*
greater than 9 m	I.B.C., Steel Beam, Box Beam* or 6 Cable Guide Rail with steel posts

* Box beam may be used if the posted speed is less than 80 km/h.

Concrete is not recommended on medians greater than 9 metres in width, because of the cost of the additional pavement, ongoing maintenance costs associated with the additional pavement, and the possibility that vehicles will use the extra pavement as a driving lane. In addition, the angle at which an errant vehicle strikes the barrier has the potential to increase with offset, and at extreme angles may result in more severe injuries and damage due to ineffectiveness of the safety shape at high angles, and the unyielding nature of the concrete.

MEDIAN SLOPES

Median slopes, and particularly changes in slope, have an effect on vehicle behaviour. To minimize the adverse effects caused by unpredictable vehicle behaviour on slopes, Box Beam, Steel Beam, and IBC barriers are restricted to a maximum slope of 6:1 or flatter, and a minimum of 4.0 metres from any surface breakpoint with roll over greater than 10%. The desirable slope is considered to be 10:1 or flatter.

Concrete barrier may only be placed adjacent to paved surfaces, with a 10:1 slope or flatter. Roll over in front of concrete barrier must be no more than 10%. Slopes 10:1 or flatter must be used with 6 cable systems.

STEPPED MEDIANS

Stepped medians can cause vehicles to be airborne prior to or at the time of impact with the median barrier. Consequently vehicle trajectories must be considered when selecting the type, mounting height and location of the barrier on these medians.

Refer to Chapter 2, Section 2.10 for guidelines for barrier placement on stepped medians.

LOCAL FEATURES

On medians that separate opposing traffic lanes, and where Freeway Traffic Management System (FTMS) signs or high mast lighting are to be installed, only High Performance Barriers (Ontario Tall Wall or IBC MK-7HV) shall be used. In core collector systems, FTMS or high mast poles shall be mounted on specially designed footings protected by high performance barriers that are transitioned to standard barriers. Refer to Chapter 2, Section 2.11.

Curb and gutter also causes unpredictable behaviour when struck by an errant vehicle. Median barriers adjacent to curbs must therefore be either steel or box beam systems. Refer also to Chapter 2, Section 2.7, Table 2.7.1.

3.3.4 MAINTENANCE

Before selecting the barrier, the designer should also consider maintenance. It is strongly recommended that the district maintenance staff in the respective regions be solicited for their advice in this regard.

Maintenance factors to consider in the selection of a barrier system are include:

a) repair of damaged sections after an impact;

b) routine maintenance due to deterioration or weathering; and

c) the effect of the presence of the barrier on the cost of road and roadside maintenance.

Particular attention should be paid to traffic volume, since this has a major impact on maintenance activities, including the time needed for repairs, cost, exposure of maintenance staff to traffic and delays to the motoring public.

The maintenance costs of a particular system may offset the lower initial installation costs, particularly in areas where the traffic volume is heavy.

The following is intended to present maintenance difficulties which may be experienced by maintenance staff for the various systems. Refer to the ministry Maintenance Manual, Operating Instructions, Volume IV for detailed maintenance procedures.

SIX CABLE

Tension and mounting are critical to the operation of the six cable systems. Ensuring that these parameters are correct requires a considerable maintenance effort. Cable barriers require post replacement and re-tensioning after an impact. The material costs are low, but the barrier must be serviced after every impact, and the tension must be checked periodically.

Due to the relatively narrow target area, mounting height is critical. Guide rail posts are susceptible to frost heave, thereby increasing the mounting height of the cable. If the median is granular, care must be taken to ensure correct cross fall adjacent to the system, and that proper mounting height is maintained during grading operations.

Cable systems placed in high volume, high accident situations may require considerable maintenance. This makes this system an impractical choice for such conditions. Collision damage, even for minor impacts, usually requires immediate maintenance attention, due to the resulting substandard mounting heights and probable loss of tension.

BOX BEAM MEDIAN BARRIER

As with cable systems, box beam mounting height is critical. Therefore, repairs on box beam systems must be carried out as soon as possible after damage is reported. A box beam median barrier is also troublesome to maintain. Even minor hits result in damage to the system. To replace any damaged posts, long heavy rail sections must be removed, using mechanized equipment. Proper alignment of the post paddles and rail slots and reassembly of the tube splices are difficult. An impacted box beam may also bend or break at the mounting slots. Maintenance staff must check for cracking at the paddle slots, and for shearing of the splice plate bolts, for a minimum of 3 beam elements on each side of the point of impact and any cracked beams must be discarded.

Replacing posts is impossible during the winter months, and temporary prop-legs should be used in the interim to support the beam if not at the proper mounting height. These may represent a hazard when struck, but using of these prop legs is less hazardous then leaving the beam unsupported.

STEEL BEAM

Steel beam barrier beam sections may have to be replaced after a collision, but the extent of barrier damage is usually less than for cable, especially if channel is used. Since the posts provide lateral restraint, broken and rotted posts must be replaced immediately. Spacer blocks used to offset the rail and channel should also be checked periodically to ensure that splitting and subsequent loss of the block has not occurred. Replacement panels must be overlapped in the direction of travel for the adjacent stream of traffic.

IBC

IBC barriers require extensive and expensive repair after impact, which may offset the benefits of their large target area and increased strength. The barrier remains operational for all but the most severe collisions, and there is, therefore, no need for immediate repairs. Protruding panels or lids should be refastened or replaced immediately to avoid vehicle snagging. Replacement panels must be overlapped in the direction of travel for the adjacent stream of traffic.

IBC barriers require specialized equipment during maintenance operations, which add to the overall cost of these systems.

Since the sides of the barrier are wider than the base, removal of roadside debris is difficult. As well, drainage openings in the side of the barrier have a tendency to collect debris. Snow plow operations may also plug the drainage openings, which can lead to icing or flooding problems.

CONCRETE

Concrete barriers usually require little or no maintenance after an impact. If damaged, however, the repair costs can be high. As a temporary solution to breakouts, a steel beam element may be bolted to each side. The wider "C" type barrier has been designed principally to accommodate conventional lighting. Due to its superior strength, however, (no breakouts to date) it may be effectively used at higher truck volume locations where a high performance barrier is not warranted.

GENERAL

Grass cutting around barrier posts may increase maintenance costs due to the extra effort required. Snow removal costs may also increase with the presence of barriers. The extent of drifting, depending on the direction of prevailing winds, can increase with decreased post spacing and also with concrete and IBC barriers. In the past, concrete median barrier was not recommended for use on North-South routes, especially in snowbelt areas. MTO maintenance experience indicates satisfactory use on north-south routes. Increased drifting does occur, but has not been a significant problem.

Snow and ice accumulation in front of and on the approaches to all barriers reduces the effectiveness of the barrier, and in extreme cases may result in vaulting over the system. As weather and resources permit these accumulations should be therefore removed.

3.3.5 COST

The relative installed costs of the various barrier systems differ considerably, depending on geographic location. The cost of material may depend on availability and economies of scale. In general, however, 6 cable barrier is considerably less expensive than the other systems, and may be used where large deflections can be tolerated, where truck traffic volumes are low, and where reconstruction of the roadway section will be scheduled within approximately 10 to 15 years. Steel and concrete systems are competitive with each other in cost.

The precast concrete barrier while typically more expensive than standard slipformed concrete barrier, may be effectively used where scale of operation or climatic conditions preclude slipforming.

The designer should use the latest cost figures available from the Estimating Office as an aid in selecting the appropriate barrier. When comparing costs, the shoulder treatments as well as drainage requirements should be considered for each system. In addition to the initial construction costs, the designer should also consider the cost of maintenance. Refer also to Chapter 2.0, Section 2.14 for Cost analysis.

3.4 DESIGN AND INSTALLATION

3.4.1 LENGTH

DESIGN PRINCIPLE

All guide rail systems, although they differ in appearance and performance characteristics, have a common function. Thus they must be sufficiently strong to shield a hazard from a direct impact from the front, and if an errant vehicle enters behind the system, the length must be sufficient to allow an errant vehicle to come to a complete stop before reaching the hazard. To meet this requirement, where the terrain behind the system is not traversable, the system length shall be longer than dictated by the length of need alone.

The length required is referred to as the **Length of Need,** (see Page 0304-3), and must be carefully calculated.

The strength of all systems is based for the most part on the tensile strength of the "beam" material. For this reason, all systems must be anchored at both ends to be fully operational throughout the length of need. This anchorage can be achieved by one of three methods.

1) The guide rail may be extended beyond the Length of Need. The only application of this treatment is at a trailing end of a system not exposed to traffic in the opposite direction, such as divided highways, or one way traffic, or where the end is beyond the clear zone offset as shown in Chapter 2, Section 2.2. The extension lengths to be used are shown in Table 3.4.2.

2) The guide rail may be anchored by an approved end treatment, as specified in Chapter 5. The end treatments provide stability, either by their length, such as the flared and turned down end, or the end treatment device is anchored using cables and struts as an integral part of the systems (Typical examples are the Extruder, Eccentric Loader, and CAT). Other systems are anchored using concrete anchor blocks such as in cable or box beam systems.

3) The guide rail may be attached to rigid objects such as bridge abutments, retaining walls, smooth rock face, etc. The connection to these objects must be sufficiently strong to equal the breaking strength of the guide rail system. **It is highly recommended that all systems (except cable) that terminate in the vicinity of the rigid objects, be extended and connected to them.** Not only is this the cheapest method of anchorage, but it also provides a safer roadside, since vehicles hitting near the ends of an unattached system may be guided directly onto these adjacent hazards.

LENGTH OF NEED

The Length of Need is defined as the length of barrier system required to provide protection at any hazard. This length does not include end treatments, which are installed beyond the Length of Need, to provide protection and stability, or extensions of the systems beyond the Length of need which provide stability only. Refer to Figure 3.4.1 which illustrates the Length of Need.

The Length of Need is a function of the distance of a hazard from the travelled lanes, the location of the barrier in relation to the hazard and the travelled lanes, and the design speed of the roadway. It is determined by assuming a vehicle leaving the roadway will travel a pre-determined length, measured parallel to the roadway, before coming to a stop. This length, referred to as the Encroachment Length (E) depends on the design speed of the roadway. Encroachment Lengths for the various design speeds are shown in Table 3.4.1, and illustrated on Figures 3.4.2 and 3.4.3.

Table 3.4.1 Encroachment Lengths

Design Speed km/h	Encroachment Length (E) m
120 or more	160
110	140
100	120
90	110
80	95
70	75
60 or less	60

The Length of Need of any system is composed of two basic components, the approach length on either side of a hazard denoted as **La** and **Là** and the length adjacent to the hazard **Lh**.

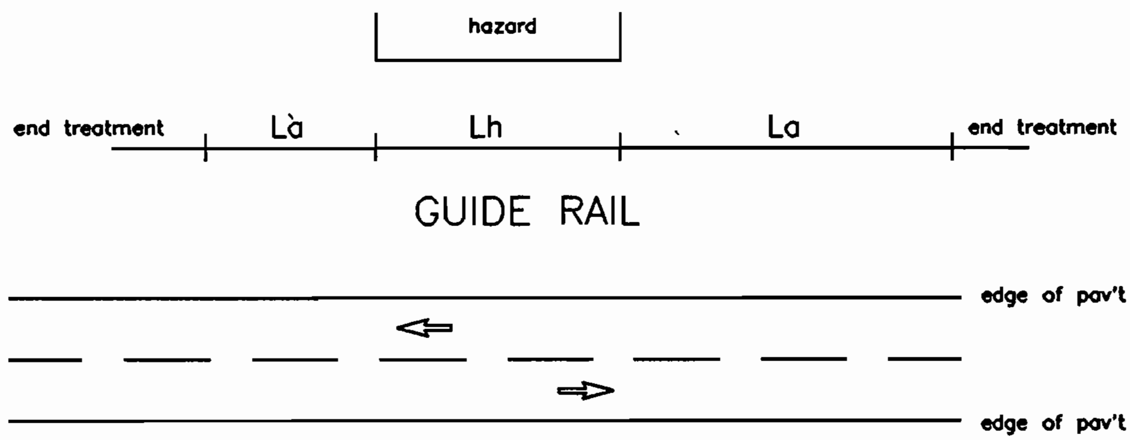


Figure 3.4.1 Length of Need

As shown on the above sketch, the Length of Need is the sum of the approach lengths La and Là plus the length adjacent to the hazard Lh.

Length of Need = La + Lh + Là

Note that on divided highways, one way roads, or where the trailing end is beyond the clear zone of the opposite lane, Là is equal to zero, and the Length of Need = La + Lh.

APPROACH LENGTH - La

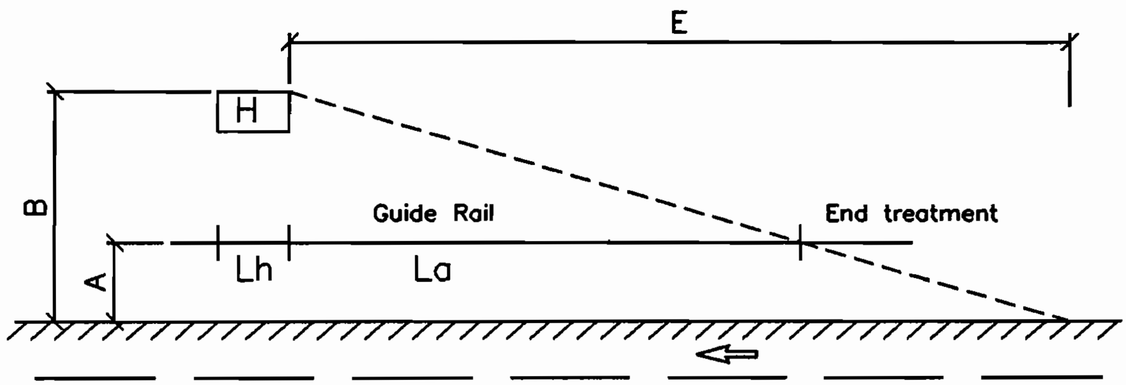


Figure 3.4.2 Approach Length La

A = distance from edge of adjacent traffic lane to the face of the barrier (m)
B = the lesser of
i Distance from edge of adjacent traffic lane to back of obstacle, (m), or
ii Clear zone width (m), (Tables 2.2.1 and 2.2.2) if hazard is continuous
E = Encroachment length (m)
La = Approach length of Barrier (m)
From similar triangles E/B = La/(B - A)
or, re-arranging **La = E (1 - A/B)**

Example illustrating the use of the Approach Length - La formula

Given:
Encroachment Length, E, = 110 m (obtained from Table 3.4.1)
Offset (B) from edge of roadway to back of hazard 6 m
Offset (A) from edge of roadway to face of guide rail is 3 m

Approach length of guide rail La = E (1 - A/B)
= 110 (1 - 3/6)
= 110 (1/2)
= 55 m

APPROACH LENGTH (Là)

Là should be used where there are restrictions on passing at the site, or where, in the opinion of the designer, the probability of passing occurring at the site is no more likely than at any other location. At locations where a passing is highly likely due to limited passing opportunity upstream, the designer may measure the A and B parameter from the edge of pavement adjacent to the guiderail as if calculating La.

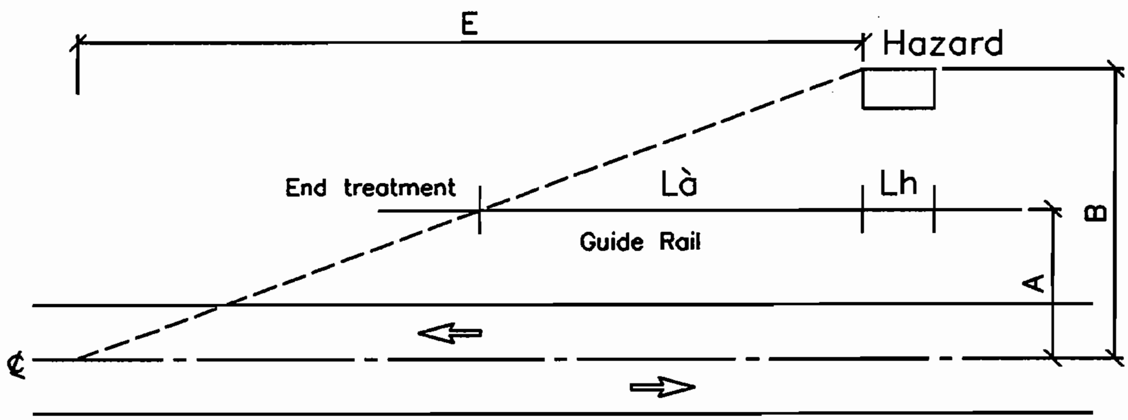


Figure 3.4.3 Approach Length Là

Approach Length **Là = E (1 - A/B).** Note that this is identical to the formula for approach length La. The difference in the two is the point of measurement of the offsets, A and B. In the approach length La calculation, the two offsets are measured from the edge of adjacent lane, while in approach length Là calculation, the two offsets are measured from the centreline of the roadway.

Example illustrating the use of the Approach Length Là formula.

Encroachment Length, E, = 110 m (encroachment length is always obtained from Table 3.4.1)
Offset (B) from centreline of roadway to back of hazard 9.5 m
Offset (A) from centreline of roadway to face of guide rail is 6.5 m

Approach Length of guide rail Là = E (1 - A/B)
= 110 (1 - 6.5/9.5)
= 110 (1 - .684)
= 110 (.316)
= 34.76 m

CONTINUOUS HAZARDS

When a hazard extends beyond the clear zone width (Table 2.2.1), it is considered to be continuous. Examples of continuous hazards are river or streams, and embankments perpendicular to traffic such as overpasses with side slopes 2:1 or steeper. In such cases the distance (B) from the edge of the lane to the back of the hazard will equal the clear zone width, which depends on the design speed of the highway. "Example 2" illustrates the method of dealing with continuous hazards.

ANCHORAGES Refer also to Section 3.4.1, Page 0304-1, Design Principle

Guide rail anchorage may be provided by installing an appropriate end treatment, or by extending the system length beyond the Length of Need.

Extension of the guide rail beyond the Length of Need to provide stability would normally be done at a location where it is unlikely that an approaching vehicle will strike the end of the system. Examples include divided highways, one way roadways, or where the end is beyond the clear zone (as specified in Chapter 2, Section 2.2.), and where the cost of the extension will be less than the installation of an end treatment. In these circumstances, the further the front face of the hazard is set back from the edge of the pavement, the less likely it is for an errant vehicle to reach the hazard if the barrier is penetrated. Consequently, part of the length of the hazard length **Lh**, (See Figure 3.4.1), performs as the anchorage (the actual length is the function of the distance from the face of the barrier to the front of the hazard). For the sake of simplicity, only the extension beyond **Lh** is presented as the anchorage length. These lengths, (shown in Table 3.4.2) represent the distance which the unanchored system must be extended beyond the hazard.

If **end treatments** are used to anchor the guide rail at locations where it is unlikely that an approaching vehicle will strike the end of the system (such as on divided highways, one way roadways, or where the end is beyond the clear zone as specified in Chapter 2, Section 2.2.), the guide rail may end at the edge of hazard, (ie. length of guide rail equal La + Lh) and instead of Extension (Table 3.4.2) an end treatment is appended. In this case, the length of the system = end treatment + La + Lh + end treatment.

Attachment to a rigid object may be accomplished using standard connections as depicted in the OPSD manual for guide rail to structure.

Table 3.4.2 Extension Length for Unanchored Guide Rails

EXTENSION REQUIRED FOR UNANCHORED GUIDE RAILS	
Distance from face of guide rail to face of hazard (m)	Extension (m)
0 - 1.5	15
1.5 - 2.5	12
2.5 - 3.5	10
3.5 - 4.0	8
4.0 - 5.0	5
more than 5.0	2

MINIMUM LENGTHS BASED ON OPERATIONAL CHARACTERISTICS

To enable the various end treatment devices to operate as designed, a specific minimum length of barrier must be installed.

STEEL BEAM WITH FLARED AND TURNED DOWN END CONNECTED TO STRUCTURE

- When the end of the steel beam system is flared and turned down (OPSD 902.05) the minimum length of the system will be 38.1 m, composed of the connection, six standard beam elements, and the four beam elements which are turned down. Note that this end treatment should be used only if the entire turned down portion is beyond the clear zone.

This minimum length is required to prevent vehicles, which may mount the system and slide along the top, from striking the structure parapet walls. This length should only be used if it is equal to or greater then the calculated length of need.

ECCENTRIC LOADER

Connected to Steel Beam Guide Rail

- When the designer chooses an Eccentric Loader as the end treatment on the end of a steel beam system, the minimum length of the steel beam guide rail will be two standard beam elements, not counting the length of the Eccentric Loader.

CAT

Connected to Steel Beam

- When the CAT is the end treatment on the end of a Steel Beam system, the minimum length of the guide rail will be two standard beam elements, exclusive of the CAT.

TREND

- The Trend end treatment may be connected directly to a permanent concrete barrier, structure parapet wall, or any rigid object.

3.4.2 EXAMPLES OF LENGTH CALCULATION

The following examples illustrate the calculation of longitudinal barrier lengths:

Example 1:

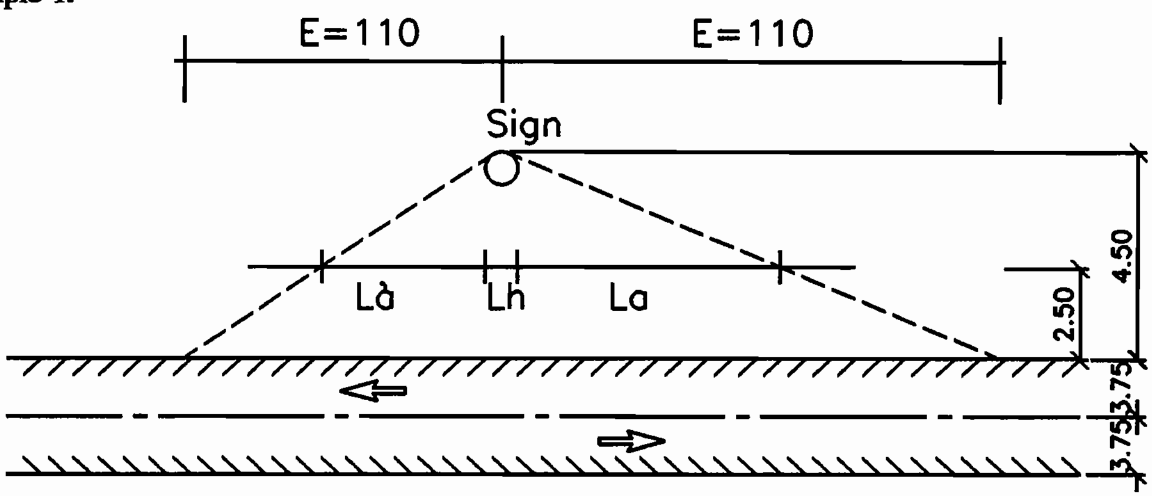


Figure 3.4.4 Example 1

Guide rail to be placed to protect overhead sign (Fig. 3.4.4).

- Existing undivided highway
- 90 km/hr design speed
- 2.5 m shoulder width
- 3.75 m lane width adjacent to barrier
- 4.5 m distance from edge of lane to back of hazard
- 0.5 m diameter sign base

Calculate La
A = 2.5 m
B = 4.5 m
E = 110 m
La = (1 - A/B) E = (1 - 2.5/4.5) 110 = 48.9

Calculate Là
Là = (1-A/B)E = (1-6.25/8.25)110 = 26.7

Total barrier length L = La + Lh + Là
= 48.9 + 0.5+ 26.7
= 71.2 m

L must be rounded up to match the number of barrier elements.

Note: The ends of the system will require both protection and anchorage. An approved end treatment will provide both.

Example 2

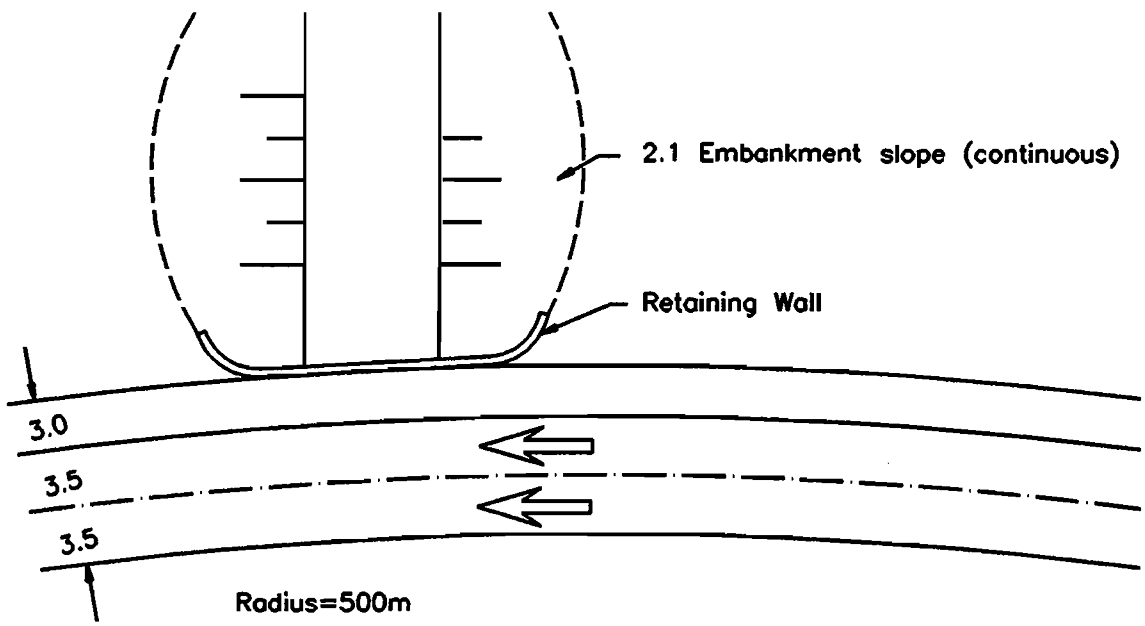


Figure 3.4.5 Example 2

- Guide rail to be placed to provide protection at a bridge retaining wall (see Fig. 3.4.5). Guide rail abuts hazard.
- 110 km/h design speed
- Horizontal Radius = 500 m
- 3 m shoulders
- Hazard "Continuous"

Therefore:

A	= 3 m
B	= Clear zone width for continuous hazard
	= 9.0 x 1.44 (Tables 2.2.1 and 2.2.2)
	= 13.0 m
E	= 140 m (from Table 3.4.1)
La	= (1 - A/B) E
	= (1 - 3/13) 140
	= 107.7 m

Note that Là is not required since it is a divided highway, and also that the guide rail is anchored at one end by the retaining wall. The other end will have to be protected by an end treatment, which also provides stability.

Example 3

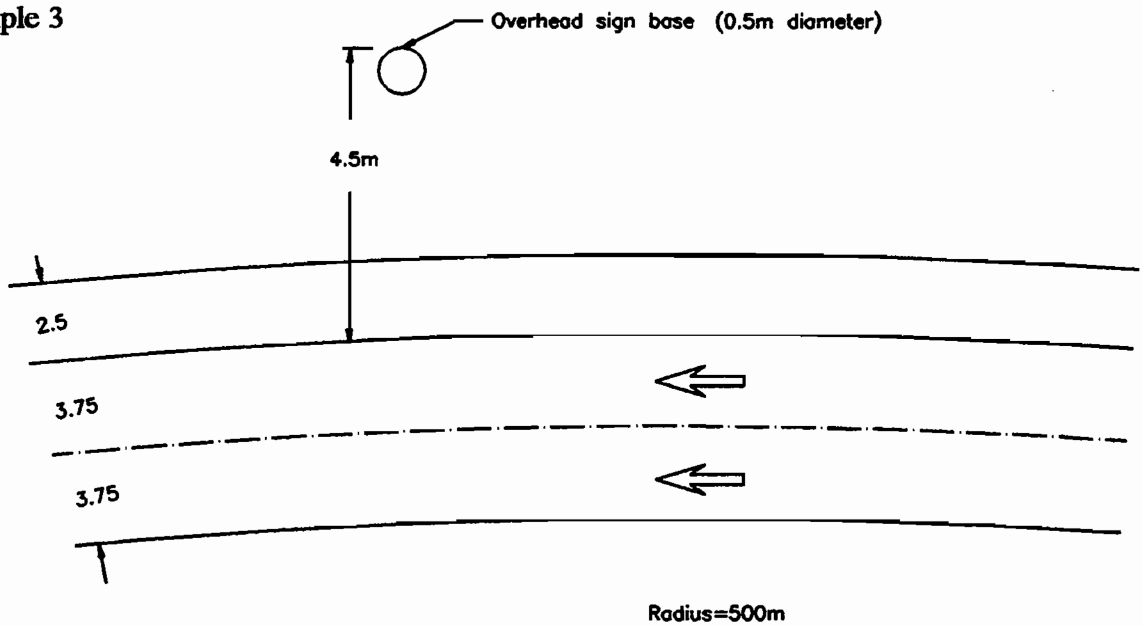


Figure 3.4.6 Example 3

- Guide rail to protect overhead sign, Fig.3.4.6
- Existing divided highway
- 100 km/h design speed
- 2.5 m shoulder width
- hazard 4.5 m from edge of pavement

Calculate La A = 2.5 m
B = 4.5 m
E = 105 m (Table 3.4.1)

La = (1 - A/B) E
La = (1 - 2.5/4.5) 120
La = 53.3 m
Calculate Là, Là = 0 Divided highway
L = La + Lh + Là
= 53.3 + 0.5 + 0
= 53.8 m

Determine extension required for stability purposes

Offset face of guide rail to face of hazard = B - A
= 4.5 - 2.5
= 2 m

From Table 3.4.2 Extension required is = 12.0 m.

Instead of extending the guide rail beyond the length of need for stability the designer could select an end treatment such as Eccentric Loader, Extruder or Cat, if cost effective.

Example 4

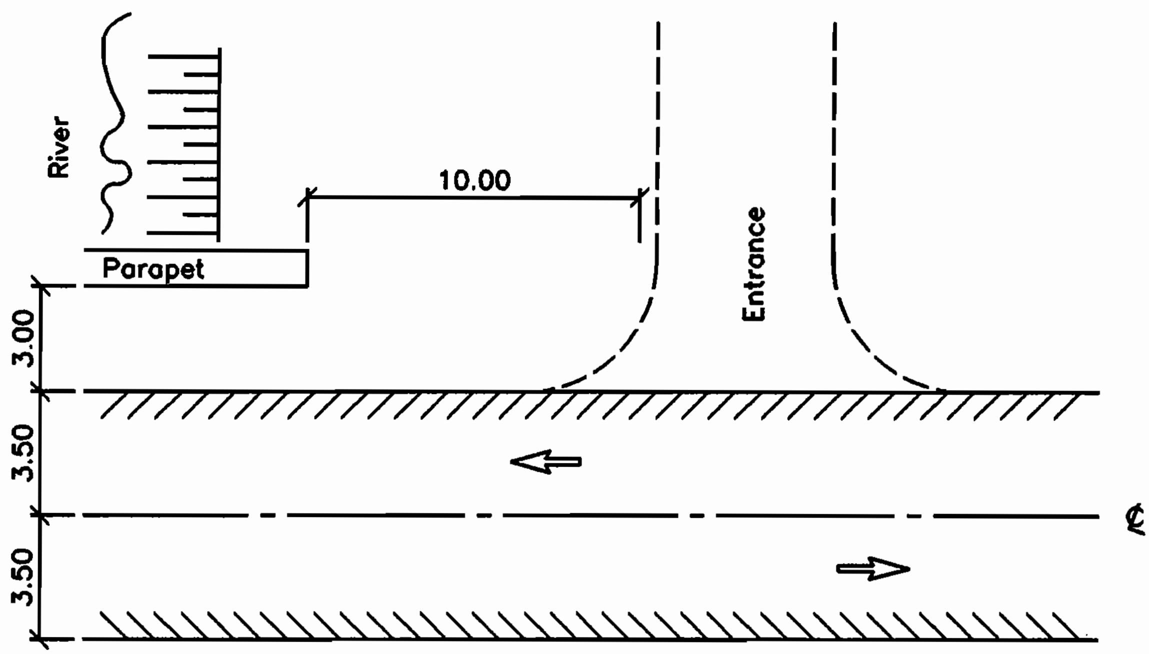


Figure 3.4.7 Example 4

- 2 lane undivided highway
- Design Speed 100 km/h
- Structure over deep river
- river continuous hazard
- offset to structure parapet wall 3 m
- entrance 10 metres in advance of structure

Calculate La
E = 120 m (Table 3.4.1)
A = 3 m
B = 7 m (Table 2.2.1)
La = E(1 - A/B) = 120(.57) = 68.4 m

The total length of guide rail required is 68.4 m. Suggested method of providing protection is as follows. Install a TREND system against the structure parapet wall, leave a gap for the entrance,and install a barrier system upstream of the entrance so that the end of the barrier is 60 m from the structure wall.

With Steel Beam Guide Rail, an Extruder, Eccentric Loader or CAT end treatment could be installed at the end closest to the entrance with An Eccentric Loader at the approach end. See Figure 3.4.8 for illustration of the installation. This treatment is expensive. If cable could be used, end treatments would not be required. See Figure 3.4.9.

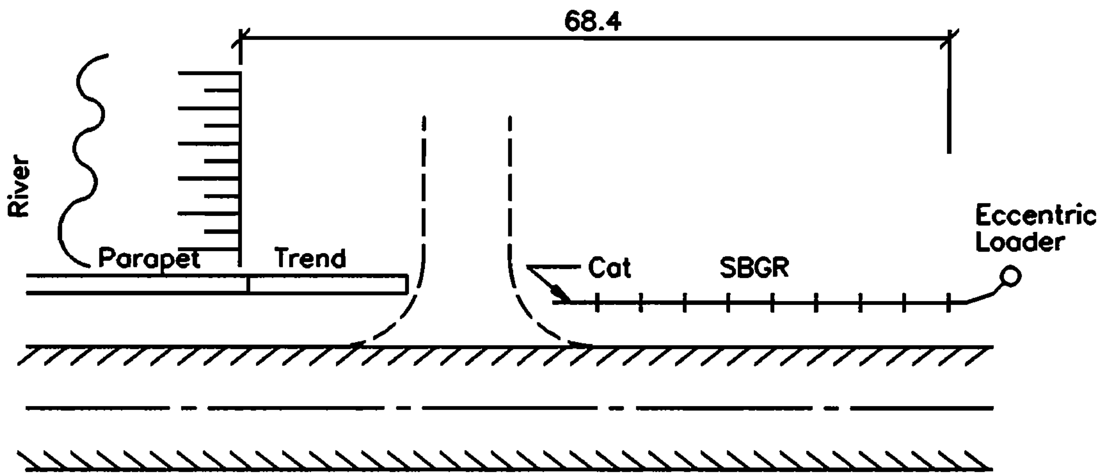


Figure 3.4.8 Guide Rail Installation at Entrance

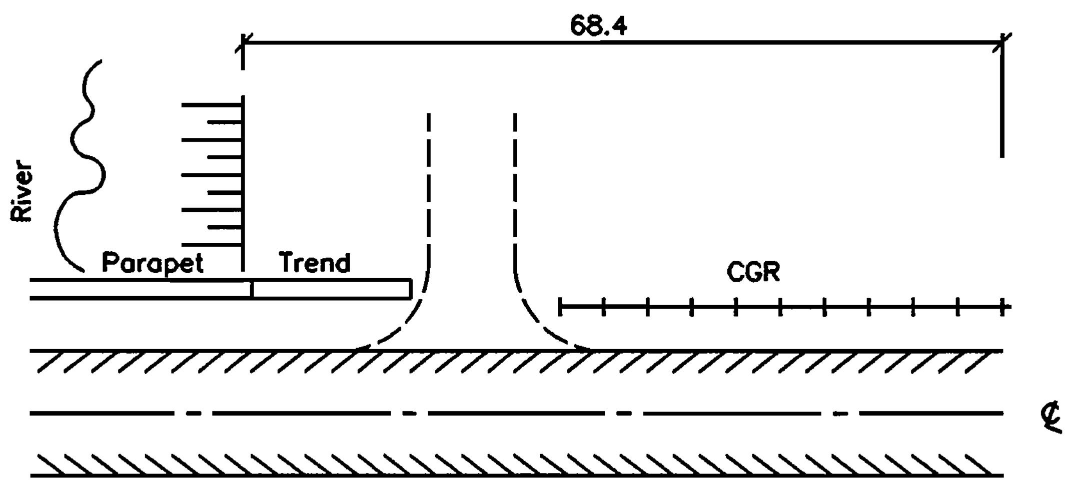


Figure 3.4.9 Cable Guide Rail Treatment at Entrance

3.4.3 LOCATION

MEDIAN AND ROADSIDE

The installation of the selected barrier system should be designed to function properly under the prevailing roadway conditions. Should more than one system be identified, based on the selection criteria, further analysis of the design details might identify the most appropriate barrier system for a particular location. Cost benefit analysis should be performed as part of this detailed analysis. Refer to Chapter 2, Section 2.14.

CROSS SECTION

Roadway cross-section can significantly affect the performance of a traffic barrier. Curbs, ditches, sloped shoulders, and stepped medians can cause errant vehicles to vault the barrier, under-ride it, or to overturn. Optimum barrier system performance is provided by a smooth cross fall in front of the barrier, provided of course that the barrier is installed correctly.

Since the behaviour of vehicles striking curb and gutter varies significantly with speed and approach angle, it is not advisable to place curb and gutter in conjunction with guide rail systems. Where curb and gutter placement adjacent to guide rail is unavoidable, there are specific guidelines to be followed. Steel beam guide rail with channel or box beam are the only systems that may be used with curb and gutter. Other types of barrier (e.g. cable, concrete, or IBC) must not be used in conjunction with any type of curb and gutter. Refer to Chapter 2, Section 2.7.3 for policy on guide rails used with curb and gutter.

LENGTH

The amount of barrier required depends primarily on the length of need, minimum length requirement, if applicable, and available traversable ground behind the barrier to allow an errant vehicle that penetrates behind the barrier to come to a safe stop before hitting the shielded hazard. This is detailed in Chapter 3, Sections 3.4.1, and 3.4.2.

CONTINUITY

To minimize the number of end treatments, short gaps between installations should be eliminated. Where the distance between the end of one installation and the beginning of another is approximately 50 m or less, a continuous guide rail system should be placed. The designer may also consider closing larger gaps between installations to achieve uniformity and aesthetic appeal.

SLOPE

If barrier continuity is not a consideration, IBC, steel, box beam, and cable barriers may be placed at locations other than the shoulder, if the slopes are 6:1 or flatter, and provided they are at least 4 m beyond adequately rounded breakpoints with a rollover greater than 10 %. The optimum slope for guide rail installation is considered to be 10:1 or flatter. Concrete barriers should not be placed more than 4 m from the travelled lane to avoid operational problems associated with the misuse of large pavement areas. The allowable rollover adjacent to concrete barriers is 10%.

OFFSET

The distance required between a barrier and a hazard depends on the deflection characteristics of the barrier system, and must exceed the probable maximum deflection of the barrier system. Semi-rigid systems can be stiffened to reduce the deflection by increasing the post size, reducing the post spacing, doubling the number of rails or providing rails of heavier gauge. However, such stiffening of barriers should be avoided, other than at transitions to structures, since it increases the possibility of snagging, pocketing, and severity of vehicle impacts.

The location of a barrier influences the number of impacts and the severity of impacts of vehicles with the barrier. The closer the barrier is located to the travelled lane, the greater the probability of a vehicle striking the barrier. Conversely, the severity of impact is usually less when the barrier is nearer to the travelled lane because the angle of impact is usually smaller. As the barrier is located farther from the travelled lanes, the probability of impact decreases, but the possibility of a more severe impact angle increases.

Preferably the more flexible barriers, such as cable steel, beam, and box beam, should be placed as far from the travelled lanes as possible to reduce both the probability of impact and maintenance expense. Usually barriers are located at the outside edge of the shoulder. However the cross-section dictates whether the barrier may be placed at other offsets. (See "SLOPE" on previous page.)

The distance from the travelled lanes to the barrier should be uniform to prevent vehicle pocketing during impact. Where variations in this distance are unavoidable, the change should take place over relatively long tapers. Flare rates for various barriers based on design speed are given in Table 3.4.3 below.

To allow for snow plowing operations the offset from the centre line of the roadway to the face of the barrier should be no less than 4.25 metres.

Median barriers are usually placed at or near the centre of the median, depending on the median geometry. On horizontal curves, due to the height of the barrier, concrete Tall Wall or IBC barriers, and possibly steel beam, may limit the stopping sight distance available. The designer should check at these locations, widen the shoulders to provide larger offset if required, or shift the barrier off the centreline.

The expected maximum deflection of the system should be less than half the median width. The cross slope on both sides of the barrier should be 6:1 or flatter, (see slope). Concrete barriers should not be placed more than 4 m from the travelled lane based, on cost consideration. Mounting height on each side of the barrier is related to the travelled lane and shoulder elevation on each side of the barrier. With slopes of 6:1 or steeper, a median barrier is not suitable, and separate roadside barriers are required on the shoulder on each side of the median. (Refer to Chapter 2, Sections 2.10.3 and to Median Barrier Selection, Section 3.3.) If twin roadside barriers are used, the designer should ensure that the deflections of the barrier systems do not overlap.

Table 3.4.3 Flare Rates for Barriers Placed Beyond the Shoulder

Design Speed Km/h	Steel Beam, Box Beam and Cable Barriers	Concrete and IBC Barriers
120	25:1	40:1
110	25:1	30:1
100	20:1	25:1
80	15:1	20:1
65	10:1	15:1
50	10:1	10:1

HORIZONTAL AND VERTICAL ALIGNMENT

The radius of horizontal curves should be considered when selecting cable and box beam barrier systems. For both cable and box beam systems, tension cannot be maintained on the outside of curves, while on the inside of curves, the barrier is ineffective because tension is lost on impact. Similarly on both crest and sag vertical curves, tension is lost on impact. Refer to Sections 3.2.3 and 3.3.3.

3.4.4 DELINEATION AND GLARE

DELINEATION

Where there is evidence of operational difficulties, the visibility of longitudinal roadside and median barriers can be enhanced by the use of reflectorized strips. This is especially useful on horizontal curves to notify drivers of approaching curves and to assist them in judging the sharpness of the curve. On tangent sections, end posts are provided with delineators to help drivers identify the beginning of a section of barrier, and also to alert the driver to the presence of the barrier system when pulling onto a shoulder in an emergency. Delineators are also used as identification markers for maintenance crews and snow plow operators. On non illuminated freeways, at District staff discretion delineators may be used on the median barrier, and particularly on concrete, to alert drivers of the barrier's location, especially in narrow medians and where the edge line is likely to be obscured by rain or snow. The delineator may be of various reflective materials or reflective paints and can be placed on the posts, rails and top or side of the various barrier systems.

For more detail concerning delineation refer to the "Manual of Uniform Traffic Control Devices", or the Traffic Management and Engineering Office.

GLARE

On non-illuminated sections of freeways with relatively narrow medians and high traffic volumes, glare from the headlights of opposing traffic may be a concern. The IBC and concrete "Tall Wall" barriers are of sufficient height to reduce glare from the majority of oncoming vehicles. For other barrier systems, anti-glare screens which fasten to the top of the barrier system have been developed.

The various anti-glare screens are invariably expensive, often exceeding the cost of the barrier itself. For this reason they should only be considered on a retro fit basis to address any existing operational problems.

On new facilities, potential glare problems should be addressed by appropriate horizontal and vertical alignment design, or by barrier selection. On detours where barrier systems separate opposing traffic, glare screens may be a desirable option.

POLICY

GLARE SCREENS ARE PROVIDED UPON RECOMMENDATION OF THE REGIONAL TRAFFIC OFFICE, AND APPROVAL OF THE ASSISTANT DEPUTY MINISTER, QUALITY AND STANDARDS.

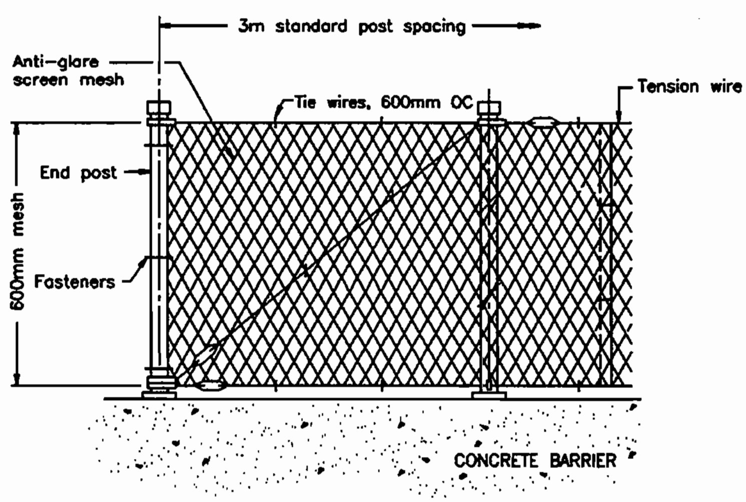


Figure 3.4.10 Median Barrier Glare Screen

3.5 END TREATMENTS, CRASH CUSHIONS, TRANSITION SELECTION

OVERVIEW

The approach ends of all guide rail systems, and isolated hazards such as bridge piers, etc., require treatment to reduce the probability of spearing, vaulting, sudden deceleration of impacting vehicles, and also to ensure stability of the system. As stated in Chapter 2.4, it is Ministry policy to use only systems and procedures documented in this manual and not to use other devices, (even though they may be approved by other jurisdictions), without authorization from the Surveys and Design Office.

Table 3.5.1 and 3.5.2 summarizes the various approved end treatments, crash cushions, and transitions.

Table 3.5.1 Summary of Transitions

Type	System Length (m)	Flare Offset (m)	Hazard Width (m) (e)	Transition Cable to SBGR			
				APPROACH		LEAVING	
				1-WAY	2-WAY	1-WAY	2-WAY
SBGR Upright End	1.0	0 or 3		X[b]	X[b]	X[c]	X[b]
Eccentric Loader	7.8	1.22		X[a]	X[a]		X[a]

a- 1.22 embankment required

b- 3.0 metre embankment widening is required on approach treatment

c- no flare is required

Table 3.5.2 Summary of End Treatments and Crash Cushions

End Treatment Energy Attenuator	System Length (m)	Flare Offset (m)	Hazard Width (m)	Shoulder End Treatment				Median Approach Treatment or Gore Areas		Comments
				APPROACH		LEAVING				
				1-WAY	2-WAY	1-WAY	2-WAY	1-WAY	2-WAY	
Turned Down										Widening Req.
SBGR	15.24	1.37		X^a	X^a	$X^{a\,\&\,f}$	X^a			Widening Req.
Concrete	10	1.50		X^a	X^a	X^a	X			Widening Req.
Eccentric Loader	7.6	1.22		X	X		X			
Extruder	15.24	0		X	X		X			
TREND	6.6	0		X^b	X^b		X^b			
CAT	9.5	0	0.6 - 5.0	X^c	X^c		X^c	X^d	X^d	See Note g
GREAT	2-9	0	0.6-1.5	X^b	X^b			X^d	X^d	
GREAT (Temporary)	3.6 or 6.3	0	0.6-1.5	X^b	X^b		X^b	X^d		X^d
C.I.A.S.	8.54	0.5	0.6-2.75					X^d	X^d	
Hi-Dro	1-9	0	1-2.75					X^d	X^d	Environmental Considerations
Hi-Dri	1-9	0	1-2.75					X^d	X^d	
Inertia Modules	3-9	0	1-5					X^e	X^e	

a- For all design speeds the turned down portion of end treatment shall be located beyond the Clear Zone offset.
b- In length restricted areas adjacent to structures, and as an end treatment for shoulder installations of concrete barrier.
c- Only where flaring of shoulder installations of SBGR cannot be constructed cost effectively.
d- Proper flaring of adjoining guide rail is required when hazard is larger or smaller than attenuator.
e- Requires a double row of modules as a minimum treatment.
f- Also used as core/collector transfer lane leaving end treatment.
g- Transition in barrier stability required at rigid obstacles.

3.5.1 END TREATMENTS

An untreated end of a barrier is extremely hazardous if hit, since the barrier can penetrate the passenger compartment, stop the vehicle abruptly, or both. A crashworthy end treatment is therefore essential if the barrier terminates within the clear zone, or is in an area likely to be hit by an errant vehicle. To be crashworthy, the end treatment should not spear, vault, or roll a vehicle for head-on or angled hits.

To select the appropriate treatment, the designer must consider specific site characteristics, and cost. When considering costs, the capital cost of the system, the modification to the roadway required to install the system, and the anticipated maintenance costs over an extended period should be included in the selection process. The designer must ensure that the embankment widening when required is included in the design cross-sections.

When the length of need is correctly used to design the length of the guide rail, this alone is not a guarantee of adequate safety. What must also be considered is that the area behind the guide rail (and the end treatment), should be fully traversable so as to allow a vehicle that penetrates behind the system to come to a safe stop before hitting the shielded hazard.

END TREATMENT FOR CABLE AND BOX BEAM SYSTEMS

Cable and box beam systems do not require special end treatment devices. They are simply turned down and anchored to buried concrete anchor blocks. In the case of box beam, the end is also flared. Any potential spearing is eliminated, but some vaulting may occur, although not readily, since cable and box beam are a weak post system. **Flaring beyond the hazard free zone should be implemented for box beam where the cross-section permits, since the minimum flare shown on the OPS drawings represent minimum treatment.** It should be noted that in design and construction, the widening of fill sections to accommodate flared terminal ends of barriers is often overlooked, and consequently terminals are flared back and down the slope or not flared at all. To provide optimum performance and protection at flared terminals, a cross-section of appropriate width is essential.

END TREATMENT FOR STEEL BEAM GUIDE RAIL

The preferred choices, of end treatment for Steel Beam guide rail are the Extruder or the Eccentric Loader. Flared and turned down ends for the steel beam guide rail may also be used if they are installed so that the entire turned down portion is beyond the clear zone offset. See Chapter 2, Section 2.2.

There are locations where the use of the Eccentric Loader end treatment is not appropriate, and where the Extruder should be used. Examples include:

1) Where extensive embankment widening is required on existing facilities. (Depending on the extent, of the widening the Eccentric Loader may still be used, however the Extruder will generally be more cost effective).

   The Extruder end treatment is installed parallel to the roadway, and therefore does not require embankment widening. The designer should compare the cost of supply and installation of the Extruder against the cost of the Eccentric Loader, including the additional fill and granular material required. The effect of the flare on ditching and drainage should also be investigated. **Under no circumstances should a toe wall or retaining wall of any kind be constructed to accommodate the extra fill requirements.** TREND although installed parallel to the roadway, is not a cost effective end treatment for steel beam.

2) Exposure to two way traffic, ie. medians, gores.

The CAT end treatment is ideally suited for applications where traffic exists on both sides of the steel beam system, in double beam applications. In gore areas a crash cushion, such as CIAS or Hi-Dro is suitable.

END TREATMENT FOR CONCRETE BARRIERS

The first choice, of end treatment for concrete barrier is the TREND. The second choice is a steel beam transition terminated by an approved end treatment, like the Extruder or the Eccentric Loader. Flared and turned down ends for the concrete barrier may also be used if they are installed so that the entire turned down portion is beyond the clear zone offset, even though this is typically costly. See Chapter 2, Section 2.2.

There are however, locations where the use of the TREND is not appropriate. Examples include:

1) Exposure to two way traffic (ie. medians and gores).

Only the GREAT and CAT end treatments are suited for applications where traffic exists on both sides of the barrier system, (ie. relatively narrow medians). The TREND is not suited for use at these locations since it has a guide cable and anchor block projecting to the side of the system. In wider medians or gore areas, a crash cushion may be suitable.

2) The TREND is not designed for the use with temporary concrete barriers.

END TREATMENT FOR THE IBC BARRIERS

The GREAT system or the CAT with concrete anchor block, are the only specified systems for the end treatment of IBC barriers.

GENERAL

All systems should be installed with a level surface leading to the treatment. The use of curb and gutter is discouraged, but if they are required, only the mountable type should be specified.

For additional information on the various end treatment systems, refer to Chapter 5, and the appropriate standard drawings in the OPSD manual. A summary of end treatment devices is shown in Table 3.5.1.

SUMMARY END TREATMENT SELECTION

The following tables represent a rule of thumb approach. The designer must still investigate the physical site restrictions such as longitudinal space, hazard width, slopes and surface type. The designer should also consider life cycle cost. At locations with the likelihood of frequent collisions, not only initial installation costs, but also cost of repair should be factored into the selection process.

Table 3.5.3
End Treatment for Roadside Guide Rails

Choice #	1	2	3
Steel Beam	Extruder	Eccentric Loader[1]	CAT
Concrete	TREND	CAT	GREAT

1. Eccentric Loader is preferred if no additional fill is required.

Table 3.5.4
End Treatment for Median Guide Rail

Choice #	1	2	3
Steel Beam	CAT	GREAT	HI-DRO/HI-DRI
Concrete	GREAT	CAT	HI-DRO/HI-DRI

3.5.2 CRASH CUSHIONS

Crash Cushions, (or energy attenuators), are devices that prevent errant vehicles from impacting fixed object hazards. This is accomplished by gradually decelerating a vehicle to a safe stop for head-on impacts, re-directing a vehicle away from a hazard for side impacts. Crash Cushions are suited for use at locations where fixed objects cannot be removed, relocated, made breakaway, and cannot be adequately shielded by a longitudinal barrier.

To select the appropriate treatment the designer must consider specific site characteristics and cost. The capital cost of the system, the modification to the roadway required to install the system and the anticipated maintenance costs over an extended period should be included in the selection process.

Presently there are six crash cushion type systems approved for use on Provincial Highways: CIAS, CAT, GREAT, HI-DRO/DRI, HI-DRO Cell Cluster, and Inertial Barrier Modules. The CAT and GREAT are also often used as end treatments.

These systems can be used to protect isolated hazards such as bridge piers, light and sign supports, as well as the approach junction of two barrier systems prevalent at gore areas.

The HI-DRO/DRI, HI-DRO Cell Cluster, and CIAS provide re-directive capabilities. Inertial barrier modules provide some re-direction only at low speeds.

The widths of some systems may preclude their use at some locations.

For optimum performance of the crash cushion there must be a clear, level run-up to the system. The use of curb and gutter is discouraged. If it is required, however, only the mountable type should be used.

The HI-DRO/DRI and Inertial Barrier Module systems can be tailored to specific applications. The CIAS currently comes in only one configuration, however other designs are being prepared. They will be contained in the OPSD manual when completed.

Inertial Barrier Modules should only be selected as a last resort, since they provide re-direction only at low speed. Their use should be limited to low risk areas, and where the cost of providing level surface would be prohibitive. See Chapter 5 for additional details concerning crash cushions.

3.5.3 TRANSITIONS

Transitions from one barrier system to another are required to ensure that the deflection characteristics are compatible at the junction of the two systems, in order to provide continuity of protection for errant vehicles. The most common transition is from a traffic barrier to a bridge parapet or wing wall.

The designer is limited to specific transition treatments for the various changes from one guide rail system to another. (Refer to Chapter 2, Section 2.4 for policy.)

Cable barrier may not be connected directly to a rigid barrier system or structure barrier wall, because of the large deflections of the cable system. Rather, the cable barrier is first transitioned to a steel beam system, with overlaps between the cable and steel beam of sufficient length and design to ensure that each system has attained its required degree of stability at the point of transition.

If the end of the steel beam cannot be installed with the correct flare, as indicated in the applicable OPSD standard, the Eccentric Loader Assembly must be used, provided there is sufficient embankment width. If there is insufficient embankment width, the steel beam guide rail can be extended to a point where the embankment is able to accommodate the flare, or the transition can be dropped and the entire system be composed of steel beam. If the above alternatives are not suitable, designers should contact the Surveys and Design Office for assistance. Also refer to Section 2.4 and 4.2.2.

Transition sections from the sand-filled steel bin barrier (IBC) to concrete barriers and concrete structure walls have been developed, utilizing stiffer side panels and positive anchorage. These and other IBC drawings are available from the Survey & Design Office. Transition treatments for various types of barriers are discussed in detail in Chapter 4. Any transition designed must take into account the deflection characteristics of the different systems.

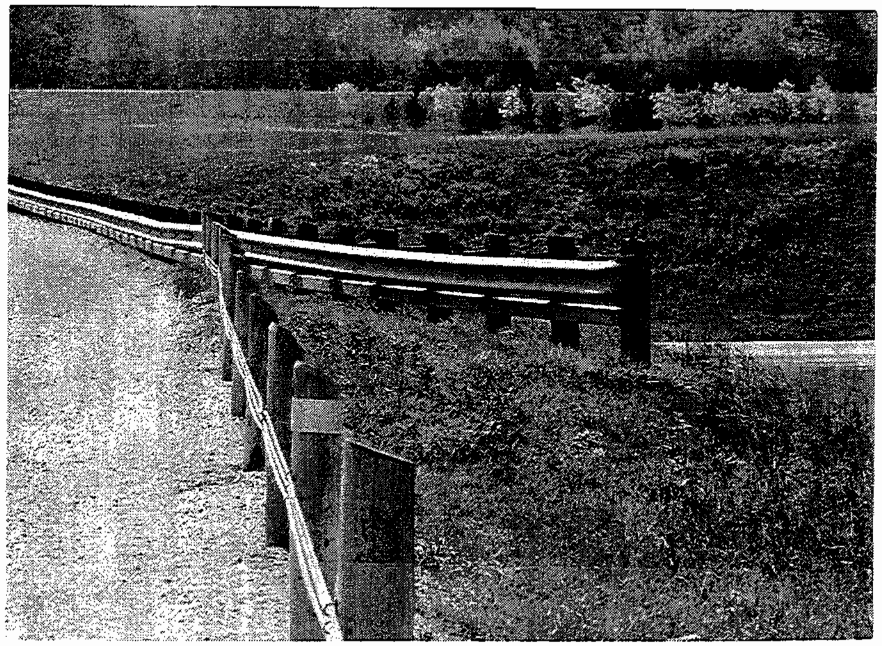


Figure 3.5.1 Transition Steel Beam to Cable

3.6 CONSTRUCTION AND MAINTENANCE

3.6.1 CONSTRUCTION

Construction plays a vital role in building a safer roadside environment. It provides an opportunity to verify the soundness of design decisions in light of physical realities in the field. New entrances may be identified in the middle of a continuous guide rail. Things may not fit. Existing structures may be to weak to accommodate a standard connection. It may be physically impossible to install reduced post spacings at structures. Guide rails may be designed without end treatments. Guide rails may not be long enough. And the list goes on.

Sometimes the design may not be appropriate or possible to construct, such as with end treatments which require flares to perform adequately, without providing widening. In this case alternative end treatments which do not require embankment widening should be selected ie. CAT, or EXTRUDER, or TREND. **Under no circumstance should retaining walls be built to accommodate extra fill.**

It is important that the construction staff become familiar with this manual to ensure that the various systems and devices are applied in an effective and safe manner. A good understanding of the manual will prevent beam elements from being overlapped so that they cause snagging; plates that are intended to telescope freely from being bolted together; beams intended to buckle to be bolted firmly in place, and so on.

The construction staff should also note if adequate traversable length exists behind barrier systems, to allow an errant vehicle that penetrates behind the system to come to a full stop before reaching the hazard. This is a common error when the design is carried out from cross-sections and plans, rather than based on a site visit.

It is recommended that in the event that a suspected design deficiency or a discrepancy in the contract documentation is noted, that the Project Manager responsible for the design contract be contacted. In the case that a non-standard design is required, the project manager may contact the Surveys and Design Office for assistance.

3.6.2 MAINTENANCE

The Maintenance Staff should be familiar with the contents of this manual. This is to ensure not only that appropriate ongoing maintenance and repair after accidents are carried out, but also to ensure that roadside deficiencies and hazards are identified. Failure to maintain or repair systems so that they will operate as intended may have serious legal ramifications. Proper understanding of roadside safety and how each system is intended to work will ensure adherence to the latest design standards, and prevent improvisations.

The operations staff should not place or store devices or signs, etc, behind guide rail systems open to vehicle penetration in such locations where they could endanger an errant vehicle coming to a stop behind the system or interfere with the operation of the barrier or end treatment.

There are several chapters specifically addressed to maintenance, namely, 2.3.2, 2.3.3, 3.2.4, 3.3.4. Chapters 4.2 and 4.3 also have sections dedicated specifically to maintenance requirements.

For specific details on maintenance procedures refer to the Ministry Maintenance Manual, Volume IV, Operating Instructions.

DETAILED TABLE OF CONTENTS

4.1 INTRODUCTION TO BARRIER SYSTEMS

4.1.1 BACKGROUND

To be effective a barrier must be capable of restraining a selected design vehicle from:

1) (a) penetrating, vaulting over, or wedging under the installation,
   (b) unless otherwise designed the barrier must also remain intact so that detached elements and debris will not create hazards for vehicle occupants or other traffic,
   (c) the system must be designed and installed so that spearing does not occur.

2) The vehicle/barrier collision should result in a smooth redirection of the vehicle at an angle which will not create a hazard to trailing or oncoming vehicles, and,

3) The collision must not result in excessive lateral and longitudinal decelerations to the vehicle occupants.

The Ministry has adopted the acceptance criteria of the National Cooperative Highway Research Programs (NCHRP) Report 230 to determine competency of barrier systems, and suitability for inclusion on provincial highways. However any system that meets the above criteria is not automatically approved for Ministry use. Unless standard drawings for the systems have been issued in OPSD format, or they are documented in a directive or bulletin and authorized by the Surveys and Design Office for experimental use, they are not to be used by the designer.

4.1.2 APPROVED SYSTEMS

The Ministry has approved as operational five basic types of longitudinal barriers for use on provincial highways. They all meet the ministry's required performance standards. However, some restrictions do apply. Refer to appropriate sections within this chapter and to the policies and guidelines in Chapter 2 and Chapter 3 for selection details.

The five basic types of guide rails with their subsets are as follows.

1) Cable

- a) 3 cable, for roadside applications;
- b) 6 cable on wood posts, for median applications; and
- c) 6 cable on steel posts, for median applications (experimental).

The cable systems, also known as flexible systems, obtain their strength from pure tension. Proper anchorage is thus vitally important, as is the need to maintain correct tension of the cables. The posts supporting the cables provide only a minor amount of restraint. Since they offer a relatively narrow target, the mounting height of these systems is critical. For more detailed information regarding cable systems, refer to the appropriate sections of this chapter, Chapter 3 and to the OPS drawings and specifications.

2) Box Beam

- a) 152.4 x 152.4 beam, for shoulder applications; and
- b) 203.2 x 152.4 beam, for median applications

Generally referred to as a "strong beam-weak post" design, or as a flexible system, these systems resist and redirect impacting vehicles by a combination of bending and tension of the hollow beam. The posts provide only minor restraint capability, even less than the cable systems since the posts are designed to separate from the beam.

For more detailed information regarding box beam systems, refer to the appropriate section of this chapter, Chapter 3 and to the OPS drawings and specifications.

3) Steel Beam

a) single beam, for shoulder applications; and
b) double beam, for median applications.

These systems, also known as semi-rigid systems, restrain and re-direct by a combination of bending and tension. Unlike the flexible systems, the posts provide significant lateral restraint. For additional information regarding steel beam systems, refer to the appropriate sections in this chapter, Chapter 3 and the OPS drawings and specifications.

4) Concrete

a) standard concrete barrier, for use on roadside and medians;
b) high performance Ontario Tall Wall, for use principally on medians; and
c) pre-cast, primarily used in construction zones.

The shape of these barriers, formerly the New Jersey shape, has been changed to the F shape, to reduce the possibility of small vehicle roll over. Existing installations of barrier which have the New Jersey shape are not considered to be substandard, and do not require modification during resurfacing or reconstruction projects. A 75 mm overlay may be used to bury the vertical face of the New Jersey shape, thus transforming it to the F shape. Even though this reduces the overall height of the barrier, crash tests have demonstrated that this has no appreciable effect on performance.

For additional information regarding concrete barrier systems, refer to the appropriate sections in this chapter, Chapter 3 and the OPS drawings and specifications.

5) **IBC (Aggregate Filled Bins).**

a) IBC MK7 primarily for use on medians; and

b) high performance IBC MK7-HV primarily for use on medians.

These two barriers differ only in the aggregate fill within the barrier. The MK-7 uses a loose aggregate, while the MK-7HV uses a cement stabilized fill material, contained in the corrugated steel bin.

The MK-7 is considered to be operationally equivalent to the standard concrete barrier. The MK-7HV which has proven capable of restraining and re-directing 36,000 kg tractor trailer units, is considered to be operationally equivalent to the concrete Ontario Tall Wall.

For additional information regarding IBC barrier systems, refer to the appropriate sections in this chapter, Chapter 3 and the OPSD drawings and specifications.

4.1.3 EXPERIMENTAL SYSTEMS

Using any system designated as experimental, requires the **approval** of the Highway Planning and Design Development Section, Surveys and Design Office, to ensure consistency of application. A monitoring and reporting program must be set up in conjunction with the Regional Traffic Offices, Regional Maintenance Offices, Traffic Management and Engineering Office, and the Surveys and Design Office. These Offices will evaluate the systems performance under actual field conditions, and determine if they should become fully operational.

4.2 ROADSIDE BARRIERS

4.2.1 SUMMARY OF ROADSIDE BARRIER CHARACTERISTICS

For additional information, refer to the appropriate section in this chapter.

Table 4.2.1 Summary of Roadside Barrier Characteristics

System	3 Cable	Box Beam	Steel Beam	Concrete	IBC MK7
Deflection	3 m	0.6 - 1.5 m	0.3 - 0.9 m	0 m	0.5 m
Minimum free standing length	Refer to Chapter 3.0 Section 3.4.2				
Minimum length connected to rigid object	Refer to Chapter 3.0, Section 3.4.2				
Equivalent Capital Cost *	1	6.0	2.5	3	8.5
Equivalent Maintenance Cost *	2.5	8	3.5	1	10

* Equivalent costs are to be used as a guide only. Contact the Estimating Office for Actual costs.

All Costs stated represent Ministry experience.

4.2.2 3 CABLE GUIDE RAIL

DESIGN FEATURES

The system consists of three steel cables mounted on 150 mm diameter wood posts, anchored by a one cubic metre concrete anchor block at each end. The maximum space between anchor blocks is 305 metres. The cables are installed on the post using a standard spacer plate and staples, or a bracket. The posts are spaced at 3.6 m maximum intervals.

See Table 4.2.2, for summary of 3 cable barrier characteristics. Refer to the remainder of this section for additional details, and to the appropriate OPS drawings and specifications .

Table 4.2.2

Summary of 3 Cable Barrier Characteristics

deflection	- to 3 m
post spacing	- maximum 3.6 m
installation height	- 685 mm (top cable)
tension	- sag maximum 6.3 mm
minimum length	- 46.8 m
maximum length	- 305 m (between anchor blocks)
minimum radii	- 250 m
placement	- roadside shoulder or slopes < 10:1
curb and gutter	- not to be used

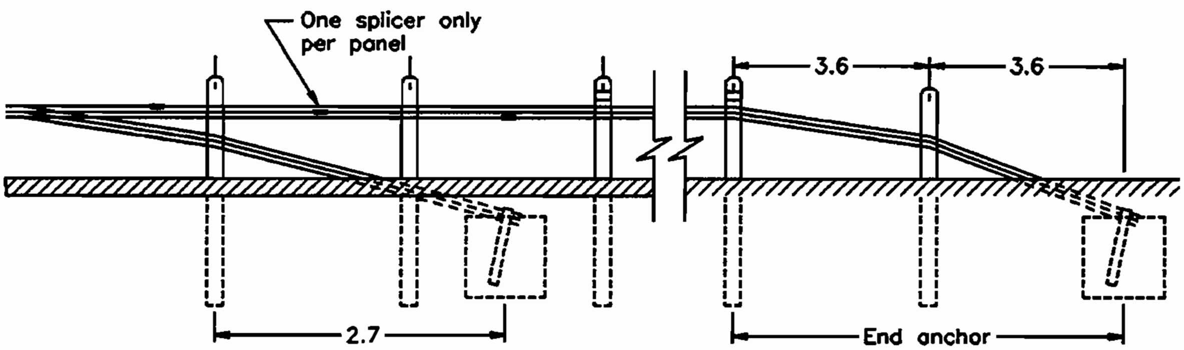


Figure 4.2.1 Three Cable Guide Rail

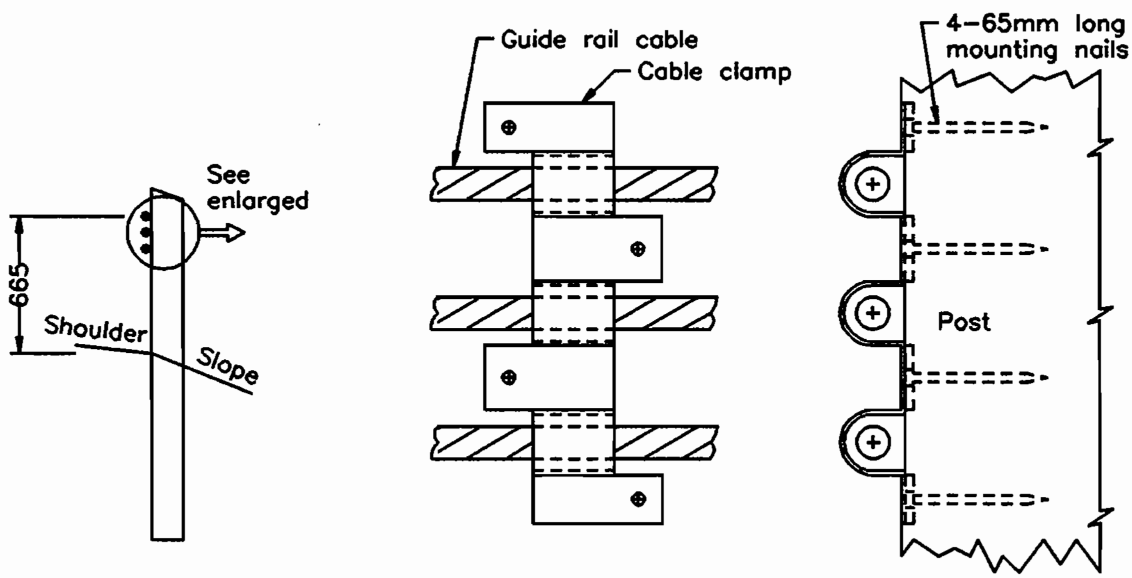


Figure 4.2.2 Bracket

BARRIER PERFORMANCE (3 Cable)

The performance of the system is extremely sensitive to mounting height and the tension of the cables. If these parameters are not correct, failure is likely to occur.

On impact by an errant vehicle, the posts hold the steel cables long enough to ensure that the steel cables are embedded in the vehicle. As the system deflects, the posts break away and the tensile strength of the cables resists and redirects the vehicle. The posts provide some lateral restraint, thus it is important that the correct embedment and minimum offset from breakpoints be adhered to, to prevent excessive deflection. Refer to "Barrier Installation", next section.

The system will deflect laterally to approximately 3 m, depending on the severity of impact.

The performance of the 3 cable guide rail system meets all required criteria for guide rail systems. However, damage to the system and/or the impacting vehicle, as well as vehicle occupant injury during a collision have been found to be substantially higher than with either concrete or steel beam systems. In addition, proper performance is less likely in collisions involving low hood, aerodynamically shaped vehicles. The initial installation costs of 3 cable systems may be lower, but when maintenance and societal costs are considered, it may prove to be more costly in the long term. The designer should consider traffic volumes and accident rates when considering this system. Refer to Chapter 3.0 Barrier Selection, and Tables 3.1.1 and 3.1.3, and Chapter 2.14 for further information.

BARRIER INSTALLATION (3 Cable)

Three cable guide rail must never be used as a median barrier on new installations. Any existing 3 cable median installations should be replaced during re-construction.

This system must <u>never</u> be attached directly to a rigid object, whether it is an alternate barrier system or any rigid hazard. Refer to "TRANSITIONS", which follows.

The 3 cable guide rail system is designed to be placed only on roadside shoulders, or on slopes 10:1 or flatter. The system may be placed on slopes as steep as 6:1, provided it is at least 4.0 metres from any surface breakpoint, and the breakpoint is smoothly rounded.

To allow for snow plow operation, clearance from the centre line of the roadway to the face of the system should be a minimum of 4.25 metres on new installations. For existing installations consult with the District Maintenance Office.

Clearance from the guide rail to a fixed object or hazard must be a minimum of 3 m, to allow for deflection of the system.

Mounting height of the top cable is to be 685 mm, measured at the base of the post. Proper tension results in a sag of 6.3 mm or less between posts. Post spacing is a maximum of 3.6 metres, with 1.2 metre minimum embedment.

Cable guide rail is not to be placed in conjunction with curb and gutter. If curbs are unavoidable, only steel beam guide rail with channel, or box beam if mountable type curb and gutter is provided, should be used. REFER TO SECTION 2.7.3 and the sections dealing with Box Beam and Steel Beam Guide rail systems in this Chapter.

To avoid reduced lateral post restraint on shoulder installations, the shoulder rounding width behind the posts should be maintained at a minimum of 0.5 m.

The minimum length of installation is 46.8 m, with a maximum of 305 m between anchor blocks. If the systems length is greater than 305 m, but less than 610 m, the anchor block spacing should be balanced.

If the system must be used on horizontal curves, which is not recommended, the minimum radius of installation is 250 metres. Tension cannot be maintained on the outside of curves, and if the inside curves are struck, tension is lost and deflection will be much greater than 3 metres.

For additional details on installation and location of guide rail systems, refer to section 3.4.

END TREATMENT (3 Cable)

The 3 Cable guide rail system is anchored to a buried 1 cubic metre concrete anchor block. The anchor block may be cubic or cylindrical. The end of this system does not require flaring, since it is not considered to be a hazard. For additional information on end treatments, REFER TO SECTIONS 2.4.1, 3.5.1, and the appropriate drawings and specifications in the OPS manuals.

TRANSITIONS (3 Cable)

Connection of a cable system to a rigid object or structure is unsafe. Significant differences in deflection characteristics, up to 3 metres, will cause pocketing or snagging in the system, and possible roll over for impacting vehicles travelling from flexible to rigid systems or vice versa.

Approach and leaving end treatment of cable to STRUCTURE is a combination of two transitions; cable to steel beam, and steel beam to structure. The cable to steel beam transition can be constructed using one of two approved methods.

1) Raised Steel beam end flared. This method may be used only at locations where the 3 m flared end can be fully accommodated on the embankments, as indicated in the applicable OPS standard, and Figure 4.2.3.

2) Steel beam end treated with the Eccentric Loader. This treatment also requires the

embankment to be widened, but to a lesser extent than the first treatment described above. Refer to the appropriate OPS drawing, and Figure 4.2.4.

If the embankment is not wide enough to accommodate either of these two treatments the steel beam can be extended to a spot where the embankment can accommodate the flare. Alternatively, the transition can be eliminated altogether, and the entire installation can be composed of steel beam. Other transition devices may be used if the embankment cannot accommodate the required flare. Designers should contact the Highway Planning and Design Development Section of the Surveys and Design Office for additional information.

Refer to Sections 2.4.2, 2.8.1, and 3.5.3 and the design standard drawings contained in the OPSD manual for additional information.

It is important to note that the flared ends of the steel beam guide rail on both of the above transition treatments (raised and eccentric loader) require that the shoulder and associated fill be widened.

The designer should ensure that the widening are included on the design cross-sections.

On the leaving end of a divided highway structure, where the transition can not be hit from the wrong direction, (typically 25 m offset), the steel beam may remain without flare and upright.

MAINTENANCE (3 Cable)

This section is intended to familiarize the designer with maintenance features. Refer to the Ministry Maintenance Manual for detailed procedures. Refer also to Section 3.2.4 for additional information.

The cable system requires frequent monitoring, to ensure that the tension of the cables is correct, and that the mounting height of the guide rail has not changed due to frost heave. Care should also be taken to ensure that shoulder grading operations do not result in incorrect mounting height, or adversely affect drainage runoff.

Collision with the barrier, even minor ones, may result in numerous posts being broken, requiring replacement and re-tensioning of the cables. The cables must be spliced in such a manner that there is never more than one cable splice between adjacent posts.

Damaged guide rail posts require replacement as soon as possible. This is because the cable mounting height will be incorrect, due to loss of tension, which may result in errant vehicles vaulting, under-riding, or rolling over the barrier. Replacing damaged posts in the winter season is impractical when the ground is frozen. Missing posts will increase the deflection characteristics and result in sub-standard mounting heights. Staples securing the cables may pull out due to wood splitting, and it is therefore suggested that the bracket be used, nailed into solid wood.

High volume roadways increase the likelihood of the barrier being struck. This can result in increased maintenance costs, since even minor hits require repair. The increased maintenance costs may make this system more expensive in the long term, despite its lower initial installation costs. The designer should investigate this possibility, when selecting a barrier.

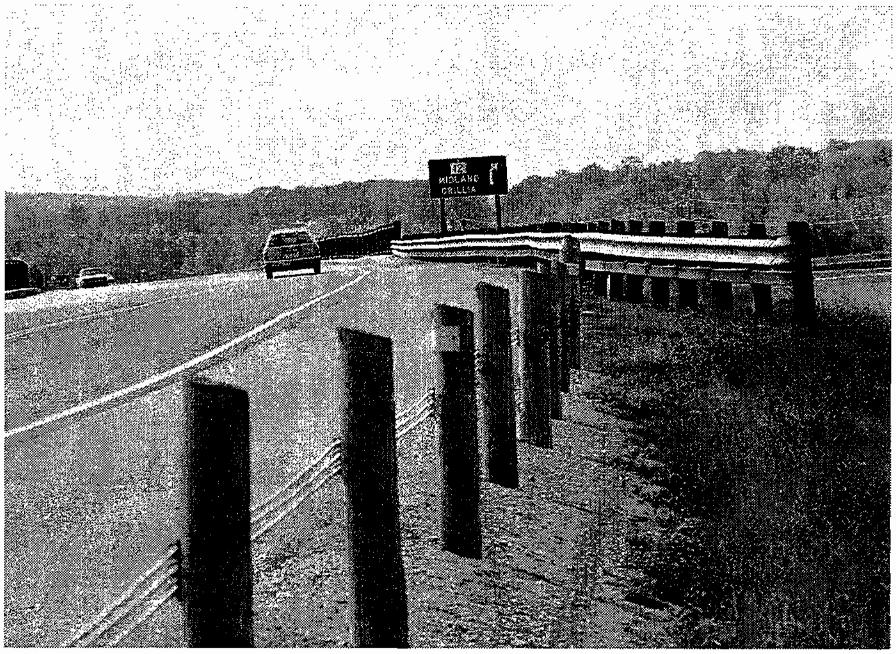


Figure 4.2.3 Transition from Cable to Steel Beam Guide Rail, End Flared

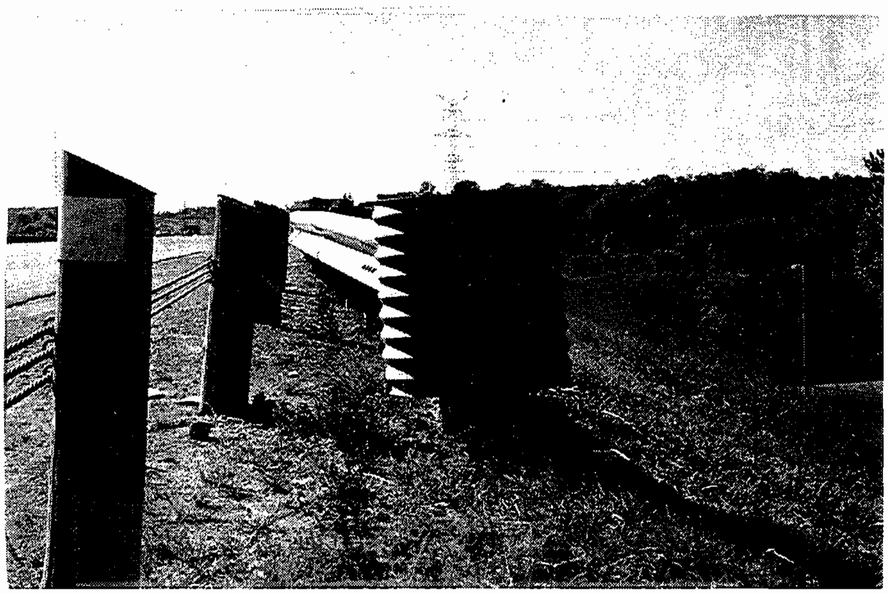


Figure 4.2.4 Transition from Cable to Steel Beam Using Eccentric Loader

4.2.3 SHOULDER BOX BEAM GUIDE RAIL

DESIGN FEATURES

The shoulder box beam guide rail consists of 5.474 m x 152.4 mm x 152.4 mm x 5 mm hollow steel beam sections. These sections are connected with self tapping fasteners to 90 x 125 mm angles bolted onto I-section posts. The box beam sections are bolted together into a continuous member with splice plates. See Figure 4.2.5.

Terminal end treatments for shoulder installations require the box beam to be turned down and bolted to a concrete anchor block. The box beam approach end treatment is flared a minimum 1.2 m from the edge of shoulder. Where room is available, greater flare is desirable.

For a summary of barrier characteristics, see TABLE 4.2.3. Refer to the remainder of this section and the appropriate OPS drawings and specifications for additional details.

TABLE 4.2.3

SUMMARY OF BOX BEAM BARRIER CHARACTERISTICS

deflection*	- 0.6 to 1.5 m
post spacing	- maximum 1.83 m
installation height	- 735 mm
minimum length	- 11 beam elements
minimum radii	- 180 m
placement	- roadside shoulder or slopes < 10:1
curb and gutter	- only mountable type

* Refer to Table 4.2.4

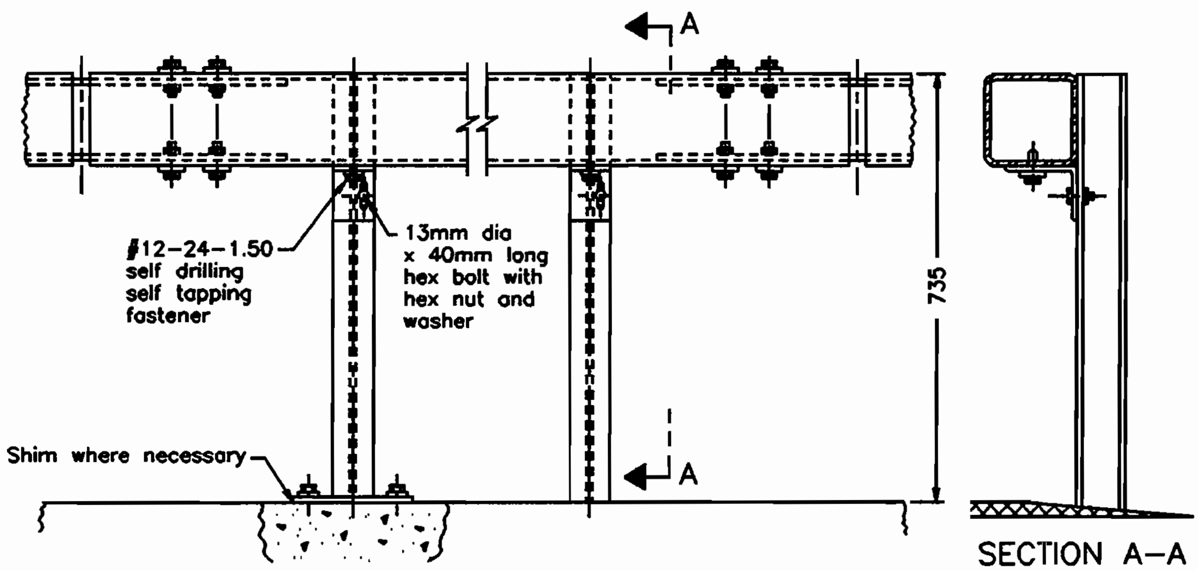


Figure 4.2.5 Box Beam Guide Rail Shoulder Installation (152.4 x 152.4 mm)

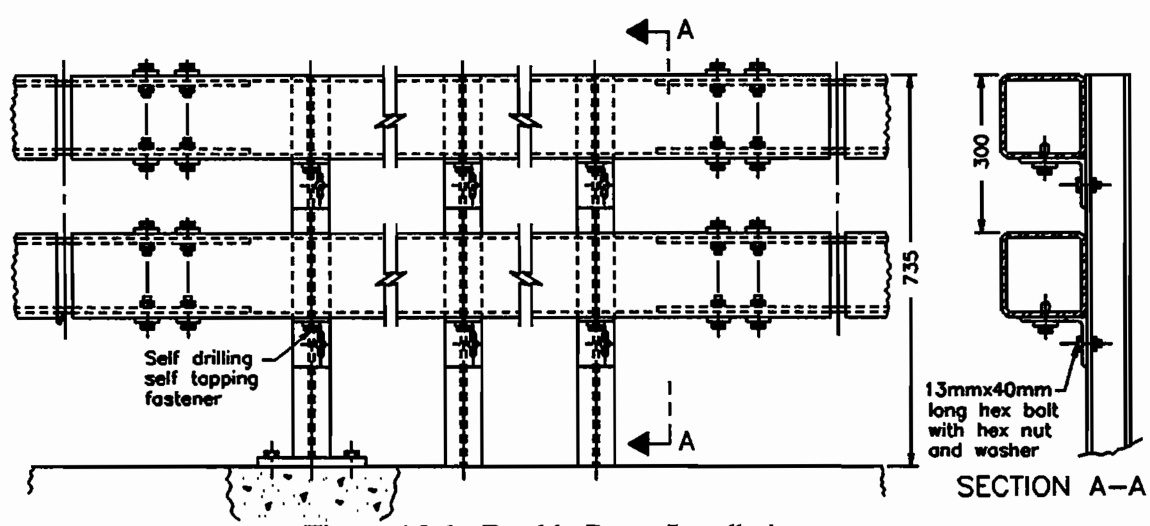


Figure 4.2.6 Double Beam Installation

BARRIER PERFORMANCE (Shoulder Box Beam)

The box beam guide rail meets all performance criteria for guide rail systems and has proven to be effective in restraining design passenger vehicles. Ministry experience, however, has shown that the amount of damage per collision, both to the barrier and vehicles, is higher for box beam than for cable, steel beam or concrete barriers. Injury severity as a result of collision with a box beam barrier is similar to cable systems.

Optimum barrier performance depends on the proper mounting height of the beam, beam connections, and the condition of the shoulder. For optimum performance, it is essential that the proper mounting height and the integrity of the connections are maintained for the full service life of the installation, and that the shoulder be smooth, with a constant slope.

Resistance to penetration in this system is achieved through a combination of bending and tensile strength of the beam. Upon impact, the self tapping fasteners shear and free the rail from the posts. The vehicle then tends to remain in contact with or very close to the beam throughout its horizontal exit trajectory. If the beam does deflect the vehicle back into the traffic it is usually at a small angle. On occasion the vehicle will "wedge" under and slide along the beam. This is also considered to be acceptable performance, however damage and injury potential does increase.

With 1.83 m post spacing the lateral deflection of the system normally does not exceed 1.5 m. The post spacing can be reduced, but this should only be done in conjunction with an additional beam, adjacent to a hazard where reduced deflection is required, or at connection to rigid objects such as concrete barriers, structures walls or bridge parapets. Refer to Table 3.2.1 for deflections of various configurations.

TABLE 4.2.4
BOX BEAM DEFLECTIONS

BOX BEAM GUIDE RAIL		
POST SPACING	DEFLECTION	
	SINGLE RAIL	DOUBLE RAIL
1.83 m	1.2 m - 1.5 m	----
0.9 m	1.0 m - 1.2 m	0.6 m

INSTALLATION (Shoulder Box Beam)

Shoulder box beam systems must not be used as median barriers. For median barrier systems, refer to section 4.3.

The barrier is normally installed at the edge of shoulder with a mounting height of 735 mm from shoulder surface to the top of the beam, measured at the face of the posts. The approach end is flared a minimum of 1.2 m, requiring the shoulder to be widened for proper installation. **Flaring beyond the minimum 1.2 m offset is recommended wherever practical, however the horizontal flare rate should be maintained.**

Similar to cable or steel beam systems the box beam system may be installed away from the shoulder provided that the slope is no more than 6:1 (preferred slope is 10:1) and that the barrier is placed at least 4.0 metres from any surface break point. As with any system, the further the system can be safely offset the better.

On new installations the guide rail should be placed a minimum of 4.25 m from the centre line of the roadway to facilitate snow plow operations.

The minimum radius for shoulder installations is 180 m, to prevent loss of tension in the system when struck by an errant vehicle.

Box Beam guide rail should not be placed adjacent to curb and gutter, unless it is the mountable type. If other type of curbs must be used, only steel beam guide rail with channel is appropriate. Refer to Section 2.7.3.

END TREATMENT (Shoulder Box Beam)

Terminal end treatments for shoulder installations require the box beam to be turned down and bolted to a concrete anchor block. The box beam approach end treatment is flared 1.2 m from the edge of shoulder. The 1.2 m flare is a minimum. In fact, the end should be offset as far as possible, provided that the slope in front of the barrier is constant, and the horizontal flare rate can be maintained. Turning down the end avoids spearing type accidents. Vaulting may occur, but is unlikely with a weak post system.

STRUCTURE TREATMENT (Shoulder Box Beam)

Approach and exit treatments at structures are similar for both the shoulder and median barrier systems. On both installations, reduced post spacing and proper anchorage to the structure is necessary. The shoulder installations require a second 152.4 x 152.4 mm beam placed 150 mm below the top beam element, as shown on Figure 4.2.6. Structure exits require a proper anchorage connection to the parapet wall on divided highways. On undivided roadways, the exit is identical to the approach treatment. Refer also to Section 2.8.1.

TRANSITIONS (Shoulder Box Beam)

When transitioning from one system to another, the transition design must allow for the variations in deflection of the individual barriers. With transitions from box beam to concrete barrier or vice versa, designers should use the structure treatment described above. Transitions to other systems are rarely encountered. If they are required, however, designers should allow for the deflection in the design. If special assistance is needed, designers should contact the Surveys and Design Office.

MAINTENANCE (Shoulder Box Beam)

Refer also to Chapter 3.0, Section 3.2 for additional information.

This section is intended to make designers familiar with maintenance features. For detailed maintenance operations refer to the Ministry Maintenance Manual.

Damage to box beam barriers, regardless of the severity of the damage, usually requires immediate attention. Bent posts are removed and new ones are driven in with portable drop-hammers. Damaged sections of the beam are unbolted, replaced and reattached to the new posts. Replacement of the beam requires the use of mechanical lifting equipment due to the size and weight of the beam. It is difficult to install new posts in frozen ground, which may lead to the barrier being unsupported for extended periods of time during the winter. Temporary prop legs should be used in the interim to support the beam at the correct mounting height. The splice plates and bolts should be checked periodically to maintain integrity and strength of the beam.

Maintenance costs with box beam systems are high, since repairs must be made as soon as possible after damage to ensure proper operation of the system, and the high cost of materials.

4.2.4 STEEL BEAM GUIDE RAIL

DESIGN FEATURES

Steel beam guide rail is a semi-rigid barrier installation which restrains and redirects vehicles by a combination of beam bending and tension. Lateral restraint is also provided by the posts. The system may be stiffened by adding a channel, doubling the beam, or reducing the post spacing.

The standard W-shaped steel beam rail, figure 4.2.7, is bolted to 190 x 190 mm wooden posts. The guide rail is offset from the posts by wooden blocks, to prevent pocketing and snagging. Refer to Table 4.2.5 for summary of steel beam characteristics. For additional, more detailed information refer to the remainder of this section, and to the drawings and specifications contained in the OPS manuals.

TABLE 4.2.5

SUMMARY OF STEEL BEAM BARRIER CHARACTERISTICS

deflection	- 0.3 to 0.9 m
post spacing	- maximum 1.905 m
installation height with channel	- 530 mm centre - 610 mm centre
placement	- roadside shoulder or slopes < 6:1
curb and gutter	- refer to Section 2.7.3

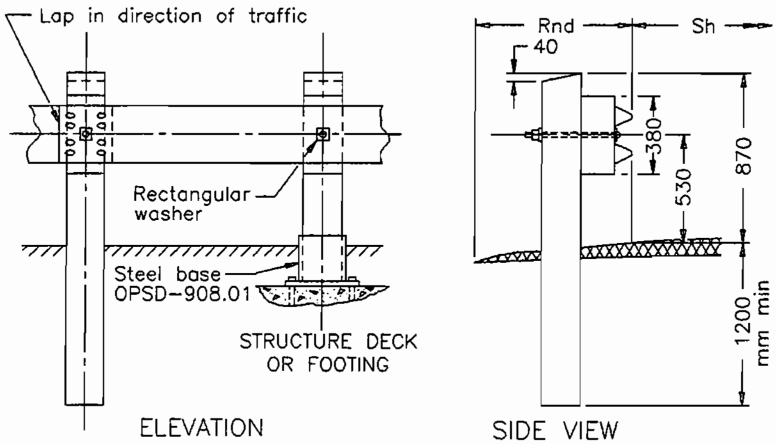


Figure 4.2.7 Steel Beam Guide Rail

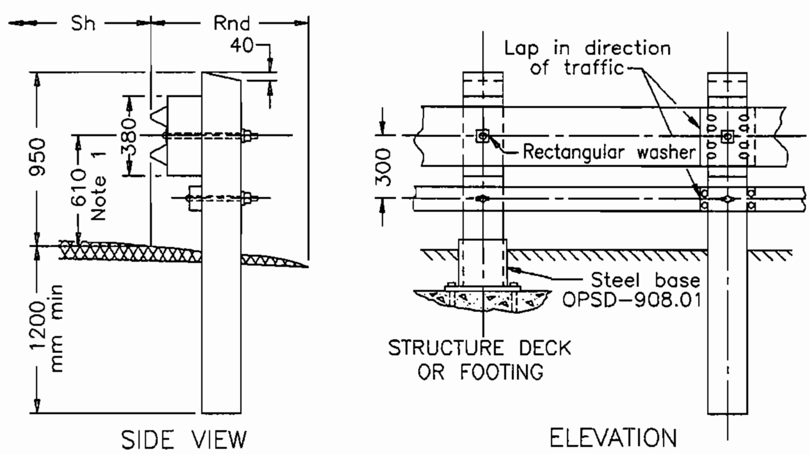


Figure 4.2.8 Steel Beam Guide Rail Single Rail With Channel

BARRIER PERFORMANCE (Roadside Steel Beam)

Steel beam guide rail is a semi-rigid barrier installation which restrains and redirects vehicles by a combination of beam bending and tension. To maintain tension all the beam elements must be properly connected. The systems posts also dissipate some of the impact energy. Optimum barrier performance depends on the proper mounting height of the beam. It is essential that this height is maintained for the full service life of the installation.

Steel beam barriers are effective on high volume highways, where the frequency of minor accidents is high and the possibility of major accidents exists. Vehicles striking the rail at a small angle and low speed are redirected at small exit angles, with only minor damage to vehicle and system. At high speeds and large impact angles, vehicle damage with this relatively rigid system may be severe. Repair costs to the system itself are moderate.

Dynamic tests show that a post spacing of 1.9 metres provides optimum resistance and allows a deflection of about 0.6 m to 0.9 m. Deflections of 0.3 m to 0.6 metres can be achieved by reducing post spacing and adding a channel. The channel increases the strength and rigidity of the installation, and will prevent front wheel snagging, thus reducing the exit angle of crippled vehicles.

BARRIER INSTALLATION (Roadside Steel Beam)

The single rail system with single offset blocks is mainly used on shoulder or roadside locations. In this situation steel channel is generally not required, but it is mandatory on approach treatments to structures, to decrease barrier deflection. At these locations the post spacings are also reduced, and an additional beam element is added. Refer to Section 2.8 and to the appropriate OPS drawings and specifications.

Beam mounting height is critical; 530 mm to the centre of the beam is the optimum height for installation without channel, and 610 mm with channel. This ensures that vehicles contact the rail at a point near, or ideally above, the vehicle centre of gravity.

Higher mounting heights allow the front of a vehicle to get under the offset beam and snag on the heavy posts, causing spinout. Lower mounting heights place the centre of gravity of a vehicle above the barrier rail. Upon impact an overturning moment is generated which may cause the vehicle to roll over the guide rail.

Steel beam with channel is the only system which may be used in conjunction with curb and gutter. The only exception is that box beam may be used adjacent to mountable curb and gutter. Refer to Chapter 2.0, Section 2.7.3 for the appropriate offsets.

Refer also to Section 3.4 for additional information regarding design and installation of guide rail systems.

END TREATMENT (Roadside Steel Beam)

Approach end

Approach end treatments for both divided and undivided highways are identical. They are to be terminated with an approved end treatment system such as the Extruder, Eccentric Loader, CAT, etc. Details of these end treatments are found in Chapter 5.0. Refer also to Chapter 2.0, Section 2.4 and selection guidelines in Chapter 3.0, Section 3.5.

Flared and turned down end section may be used only when the entire turned down portion is located beyond the clear zone, as shown in Chapter 2, Section 2.2.

Trailing end

The trailing end of a roadside steel beam guide rail installation on divided highways is to be turned down and buried. This also serves to anchor the system.

On undivided highways the roadside trailing end is treated in the same manner as the approach end treatment. This offers protection for vehicles travelling in both directions of travel.

CONNECTION TO STRUCTURES (Roadside Steel Beam)

Proper anchorage of the guide rail is essential for correct operation of the approach treatment at structures. In addition to the structure connection, a minimum length of steel beam guide rail may be required beyond the length of need, to ensure stability of the system. Refer to Section 3.4 .

Two reductions are incorporated in guide rail post spacings immediately adjacent to structures. This allows for a more gradual reduction in G forces on impacting vehicles, and a smoother transition in stiffness from the semi flexible steel beam to the rigid concrete structure. This treatment applies to structure approaches on both divided and undivided highways and to structure exits on undivided roads.

The leaving end of structures on divided highways do not usually require a guide rail treatment. Where protection is necessary at fill locations, a proper anchorage connection to the structure is required.

TRANSITIONS (Roadside Steel Beam)

Steel beam transitions to concrete barrier are identical to connection to structures, as discussed above and in Section 2.8.1.

The cable to steel beam/steel beam to cable transition can be constructed using one of two approved methods.

1) Steel beam end flared. This method may be used only at locations where the 3 m flared end can be fully accommodated on the embankments as indicated in the applicable OPS standard.

2) Steel beam end treated with the Eccentric Loader. This treatment also requires the embankment to be widened, but to a lesser extent than number one above. Refer to the appropriate OPS drawing.

If the embankment is not wide enough for either of these two treatments the steel beam can be extended to a location where the embankment can accommodate the flare. Alternatively, the transition can be eliminated altogether and the entire installation can be composed of steel beam. Other transition devices may be used if the embankment cannot accommodate the required flare. Designers should contact the Highway Planning and Design Development Section of the Surveys and Design Office for additional information.

Refer to sections 2.4.2, 2.8.1, AND 3.5.3 and the design standard drawings contained in the OPSD manual for additional information.

It is important to note that the flared ends of the Steel Beam Guide Rail on both of the above transition treatments (raised and Eccentric Loader) require that shoulder and associated fill to be widened. The designer should ensure that the widening are included on the design cross-sections.

For steel beam transition to box beam guide rail, refer to Section 4.2.3.

MAINTENANCE (Roadside Steel Beam)

This section is intended to give designers an overview of maintenance requirements. For detailed maintenance procedures refer to the Ministry Maintenance Manual. Refer also to Section 3.2.4, for additional information concerning Steel Beam Guide Rail maintenance.

Depending on the severity of impact, the repair of steel beam guide rail after collisions may require the replacement of several beam sections as well as the wooden posts. Low speed, low angle hits may not require any repair, while high speed, high angle impacts usually result in damage. Slightly damaged rails will continue to perform adequately, but the connection between beam elements must be sound to ensure continuity.

4.2.5 IBC MK-7 BARRIER

The IBC barrier has not yet been used as a roadside barrier by the ministry, but may be feasible at specific and unique locations.

DESIGN FEATURES

IBC Mark 7 barrier, Figure 4.2.9, is a continuous, granular filled steel bin design, which absorbs energy and restrains errant vehicles by a combination of barrier movement, elastic deformation of the steel panels, and displacement of the fill.

The barrier components are made of galvanized, or plastic coated steel for colour and added weather protection. The system is covered with a lid and can be filled with either sand or gravel. The open bottom design is free draining.

The IBC Barrier is preformed, pre-drilled and bolted together on the site, with the use of jigs. Each section is 3 m long, joined by section bulkheads, which separate each bin section. All sections are granular filled. Lids are added to complete the barrier after the filling operation.

The use of the barrier requires a minimum 3 m offset from the edge of pavement. Since the barrier does deflect on impact, the shoulder behind the barrier must be extended 500 mm, just as with the concrete barrier.

TABLE 4.2.6

SUMMARY OF IBC MK-7 BARRIER CHARACTERISTICS

deflection	- 500 mm
height	- 1070 mm
minimum length	- 30.0 m
placement	- roadside shoulder or slopes < 10:1
curb and gutter	- not to be used

PERFORMANCE
INSTALLATION
END TREATMENT
STRUCTURE TREATMENT
TRANSITIONS
MAINTENANCE

Since the IBC MK7 barrier will be used mainly as a median barrier, refer to Section 4.3, IBC median barriers, for more detailed information.

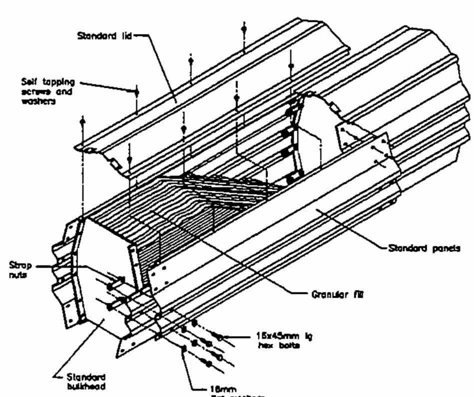


Figure 4.2.9 IBC MK7 Barrier

4.2.6 STANDARD CONCRETE BARRIER

NOTE: FOR INFORMATION ON PRECAST CONCRETE BARRIERS, REFER TO SECTION 4.2.7

The basic concept of the concrete median barrier was developed in New Jersey. The shape and height were determined largely by trial and error. Subsequent designs established the height at 825 mm, which was high enough to restrain most vehicles, but not high enough to obscure the drivers view and allowed for 75 mm asphalt overlay adjacent to the barrier. Recently the New Jersey shape was modified and the Ministry has adopted a variation called the F shape. This shape has been crash tested and found to prevent rollovers of small cars at the bottom of the design vehicle range.

DESIGN FEATURES

Today the concrete median barrier, Figure 4.2.10, consists basically of three sections:

1) a 75 mm vertical base section which is buried in the surrounding pavement structure;
2) a 55 degree sloped section, to 250 mm in height above pavement; and
3) an upper vertical section sloping upward at the rate of 10:1, bringing the barrier to its full height of 825 mm from top of pavement.

TABLE 4.2.7
SUMMARY OF STANDARD CONCRETE BARRIER CHARACTERISTICS

deflection	- 0.00
height	- 825 mm
minimum Length	- 30.0 m
*placement	- paved roadside shoulder or paved slopes < 10:1
curb and gutter	- not to be used

* The shoulder in front of the barrier must be paved, and the shoulder widened 0.5 m behind the concrete barrier.

PERFORMANCE
INSTALLATION
END TREATMENT
STRUCTURE TREATMENT
TRANSITIONS
MAINTENANCE

Refer to Section 4.3.6, Concrete median barrier, for more detailed information.

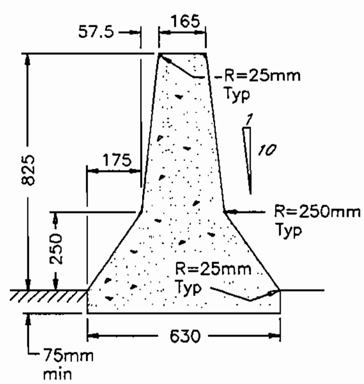


Figure 4.2.10 Concrete Barrier

4.2.7 PRECAST TRAFFIC BARRIERS

DESIGN FEATURES

Precast concrete barriers, shown in Figure 4.2.11, are widely used in work zones to protect both motorists and workers. However, improper use of these barriers can provide a false sense of security for both. Care must therefore be taken in their design, installation and maintenance. They must provide the same level of safety as permanent barriers on roadways with the same posted speed.

Precast concrete sections are normally 4 metres in length with built-in connecting devices. Their weight is approximately 600 kg/m depending on the exact cross section geometry and the amount of steel reinforcement. The weight of individual segments is approximately 2400 kg, thus requiring heavy equipment for movement. Adequate longitudinal reinforcement and positive connections ensure that the individual sections act as a smooth, continuous unit.

PERFORMANCE

When struck by a vehicle, the mass of the precast barrier and friction between the unit and the underlying surface limit both movement and overturning. Each section must be properly connected to the adjacent section to provide enough continuity to resist movement. Performance may be enhanced by anchoring the barriers to the underlying surface preventing lateral movement. This can be done with drift pins or anchor bolts attached to the pavement or bridge behind the barrier.

To perform properly and redirect vehicles as designed, the barrier system must be capable of withstanding severe impacts. The weakest point is usually the connection, including the physical connection and the mating faces of adjoining barriers.

PRECAST BARRIER CONNECTIONS

A number of different barrier connections have been used in Ontario, but only three remain in use. These are the "I Lock", Concrete Key, and the Hook and Eye. The Ministry has recently standardized the "I Lock" as the preferred connection for temporary barriers. All other types have been, or are being phased out. To allow contractors to replace current stocks of temporary barrier, the following implementation schedule had been established in 1988.

For contracts awarded on or before December 31, 1992, contractors may use precast concrete barrier units with one of the following connections:

I-Lock,
Concrete Key, or
Hook and Eye.

For Contracts awarded after December 31, 1992, contractors shall use only precast concrete barrier units with I-Lock connection on:

a) divided roadways with two or more lanes in each direction; and
b) on other roadways with posted speed of 80 km/h or greater.

For contracts awarded on or before December 31, 1995, contractors may continue to use one of the above connections on:

c) roadways with posted speeds less than 80 km/h.

For contracts awarded after December 31, 1995, only the I-Lock connection shall be permitted on any roadways.

I-LOCK CONNECTION

The I-Lock Connection, shown in Figure 4.2.11, is a barrier connection developed by the Ministry for an "F" shape barrier from a similar American design, the New York Connection. The barrier consists of concrete segments 3.6 to 4.0 metres in length. Each segment has a male and a female end. The male connection consists of a vertical steel I Section cast into the barrier end with the flange and part of the web protruding. The female end has a slotted channel embedded flush with the face of the barrier. Segments are connected by lowering them into place with the connections engaged between adjoining barriers to form a continuous wall. Individual barrier segments can be removed without disturbing the others. The end tapered down section abutting standard units is always female. A female to female connection, when required, is accomplished by dropping an I section into the channels. The end sections have a provision for a drift pin to provide anchorage.

This barrier connection can develop relatively high tensile, moment, shear and torsional strengths. The original New York design was successfully crash tested and has met permanent barrier performance standards. The I-Lock connection has successfully performed in the field and redirected passenger and commercial vehicles, without penetration.

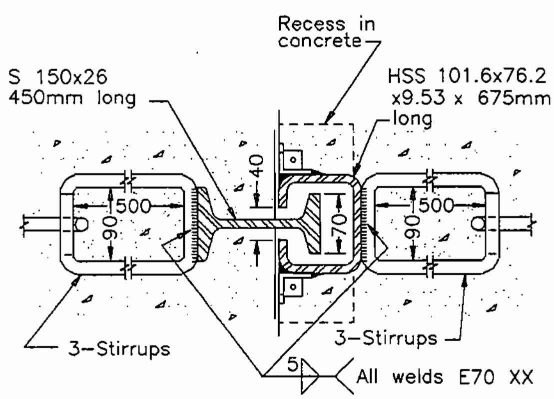


Figure 4.2.11 I-Lock Connection

HOOK AND EYE CONNECTION

This barrier connection is designed for New Jersey shaped concrete segments that are 4.0 metres long. On one end of each unit, a loop of reinforcing bar protrudes at a height of 450 mm above the base of the barrier. The other end has a corresponding hook of reinforcing bar protruding in an 80 mm deep slot, recessed in the loop of the adjacent barrier.

This joint can develop moderate strength in tension and shear but is significantly weaker than the I-Lock connection. Once a unit has been displaced sufficiently from its neighbour, the barrier end becomes a hazard and breakthrough by vehicles can occur.

Unlike the I-Lock connection, the hook and eye connection makes it is difficult to remove a panel from within an installation. The hook end of one unit must be lifted while the adjacent unit is dragged out of the line.

CONCRETE KEY CONNECTION

The Concrete Key connection is a proprietary design in which a 3.66 m long New Jersey shaped barrier segment with a triangular male key butts into a female keyway on the adjacent unit. The barrier consists of two types of unit, each with either two female or two male ends. Exposed corners of the key and keyway are protected by steel shields to prevent chipping of the concrete.

Although the joint can withstand shear, it has no tensile or moment resistance. Once a unit has been displaced sufficiently to disengage from its neighbour, the barrier end becomes a hazard and breakthrough by vehicles can occur.

END TREATMENTS (Precast Barriers)

The desirable treatments for exposed ends of barriers are:

- connecting to an existing barrier, see figures 4.2.14, 4.2.15, 4.2.16;
- attaching a crashworthy end treatment or crash cushion; or
- ensuring that the entire turned down portion of the flare is beyond the clear zone offset, as specified in Chapter 2.2.

Refer also to Chapter 2.0 Section 2.12.1, which shows a method of protecting the ends on detours.

APPLICATIONS (Precast Barriers)

Refer also to Chapter 2.0, Sections 2.12.

The minimum length of a portable barrier system should be 45 metres. The tightest curve that the I-Lock allows in terms of placing is approximately 45 m.

Openings in the barrier should be avoided if possible. Short openings up to 1.5 metre may be spliced with a steel beam. Where necessary, the barrier ends should have an acceptable end treatment or offset. For better night visibility, reflective devices may be mounted along the barrier. Refer to the MUTCD for guidance.

MAINTENANCE (Precast Barriers)

The damaged units may be repaired by concrete patching. Where the connection has been displaced or torn out (typically after a truck/van hit), repair is feasible. Units with repaired connections should be used only on lower speed facilities.

The drainage slot under the units must be kept clear of debris, to allow for free passage of water. This is particularly important during the winter season when ponding or freezing on the roadway may occur.

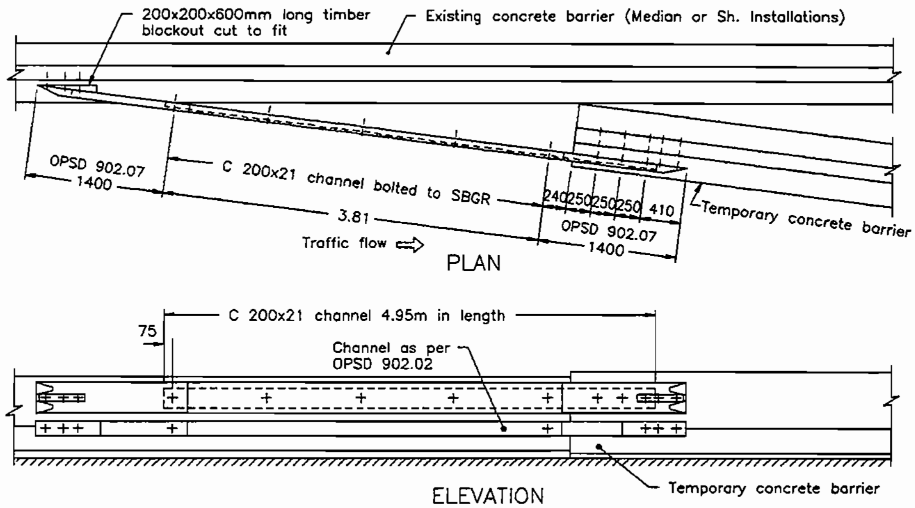


Figure 4.2.14 Temporary Connection to Concrete Barrier

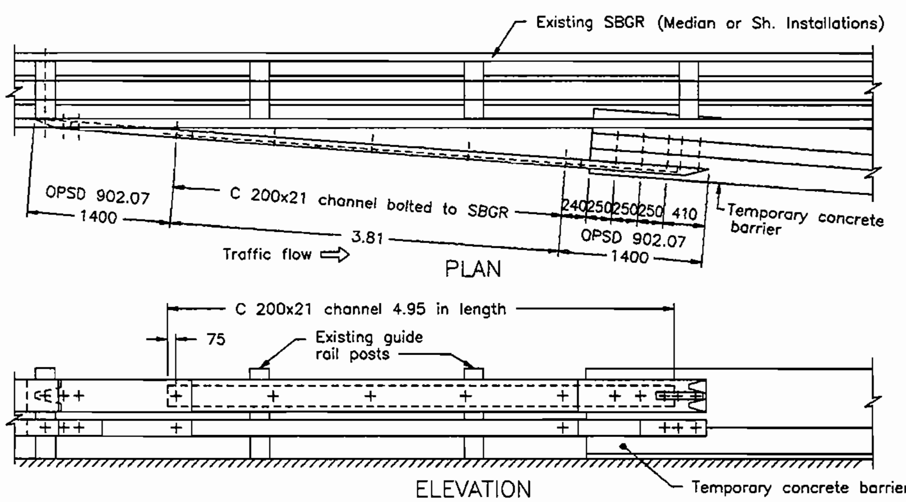


Figure 4.2.15 Temporary Connection to Steel Beam Guide Rail

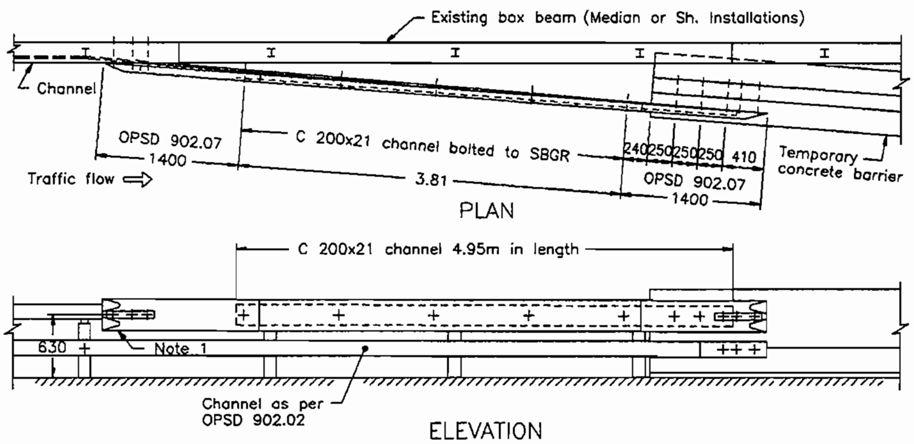


Figure 4.2.16 Temporary Connection to Box Beam Guide Rail

4.2.8 PRECAST NOISE/TRAFFIC BARRIER

Noise barriers are considered to be a roadside hazard, and must be treated as such. One acceptable alternative for providing protection is to install a noise barrier on top of a concrete traffic barrier instead of placing the noise barrier behind the traffic barrier. Precast concrete noise/traffic barriers have been developed specifically for this application, (see Figure 4.2.17), and are to be used only in conjunction with mounted noise barrier installations.

DESIGN FEATURES

The precast concrete sections are 1.1 m high and normally 3.625 m in length. The length, however, may vary depending on the manufacturer of the noise barrier system. The barriers are reinforced to meet the requirements of the Ontario Highway Bridge Design Code. The barrier weight is approximately 867 kg per lineal metre. Each end of the traffic barrier is designed with a 90 mm deep vertical groove. This groove then interlocks with the flanges of the vertical I-beams which support the traffic barrier and the noise panels above.

PERFORMANCE

When struck by a vehicle, the positive connection to the noise barrier posts, the combined mass of the traffic and noise barrier, and the friction between the unit and the underlying surface tend to limit the movement and overturning motion of the traffic barrier. Since these barriers are identical in shape to concrete barriers their performance is also acceptable.

INSTALLATION

Since the weakest point is usually at the connection to the post, care must be taken to ensure that post space tolerances are strictly adhered to.

It is critical to note that when this type of traffic barrier is used, the post strength and footing size for the noise barrier system must be designed as if the full height of the noise barrier were to be 5 m high, regardless of the actual height of the noise barrier required.

This traffic barrier should only be used in conjunction with noise barrier installations.

The shoulder adjacent to the barrier must be paved, and curb and gutter is not to be used.

END TREATMENTS (Precast Noise/Traffic Barriers)

End sections must be protected by an approved end treatment or crash cushion, or flared away from traffic beyond the clear zone.

MAINTENANCE (Precast Noise/Traffic Barriers)

Units sustaining minor damage may be repaired with concrete patching material. However, if the connection at the post has been damaged to a point where it is unable to function at its full design strength it must be replaced . If the post has been damaged or bent it must also be repaired or replaced.

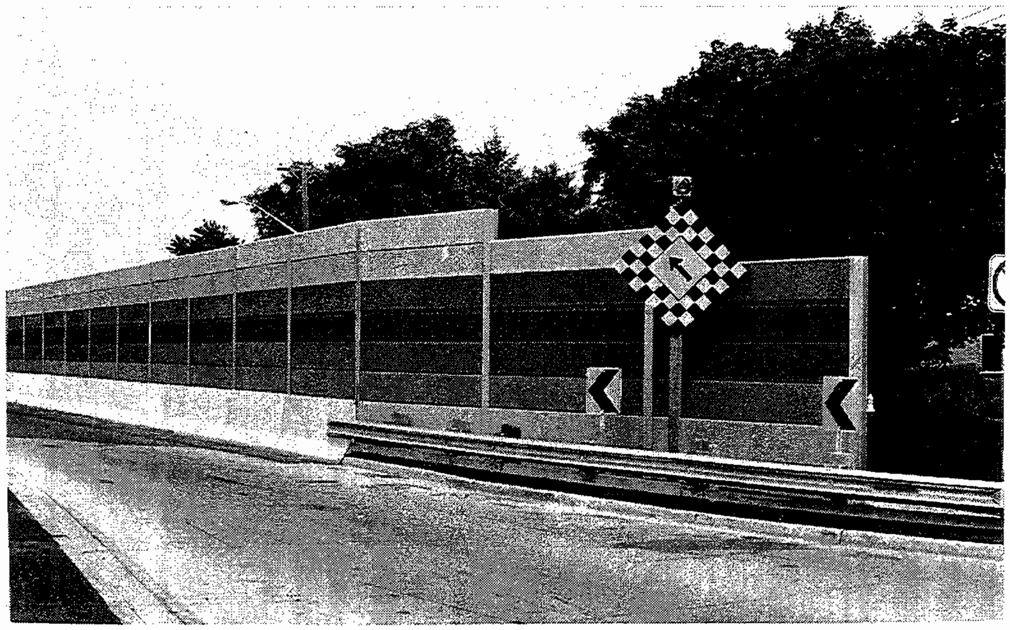


Figure 4.2.17 Precast Noise/Traffic Barrier

4.2.9 QUICK CHANGE MOVEABLE BARRIER SYSTEM

DESIGN FEATURES

This proprietary portable barrier system shown in Figure 4.2.18, is composed of a chain of New Jersey shaped concrete barrier segments 940 mm in length which can be readily shifted laterally. Steel rods run the length of each segment, and specially designed hinges are attached to either end which are then joined by pins. The top of each segment is "T" shaped to allow pick up by a special vehicle. The 'T" slot is engaged by the vehicle conveyor system and the segment is lifted from the road and can be moved laterally from 2.4 to 4.9 m. Continuous lengths of the barrier are transported on conveyor wheels through an elongated "S" curve, moved across the roadway and set down to form a new parallel lane. Transfer speeds of 8 to 16 km/h are obtained depending on the lateral distance of movement.

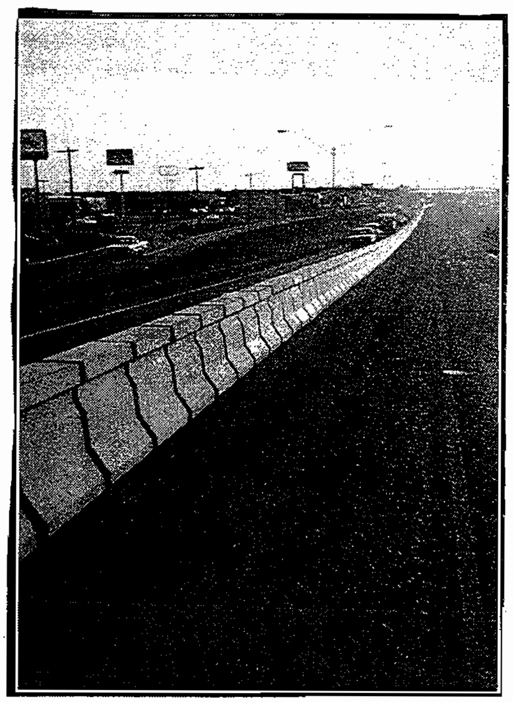


Figure 4.2.18 Quick Change Moveable Barrier

PERFORMANCE

The system has been successfully crash tested with a 2300 kg vehicle at 90 km/h and 25 degrees. This test resulted in a deflection of approximately 1.5 m.

DESIGN and INSTALLATION

The system may be used in constructions zones on high volume freeways, particularly when traffic lanes are opened and closed frequently due to construction operations and a desire to maintain traffic capacity. The system involves considerable initial cost, energy and time to set up, but it allows a work zone to be quickly created and protected during periods of low traffic flow, and to be changed back to full lane utilization during the busy daytime period.

The system may also be used effectively on roadways with unbalanced directional traffic, such as commuter or tourist routes. Once set up the barrier can be moved rapidly to provide additional capacity in the direction of heavy traffic flow.

Since this system is experimental, designers should contact the Surveys and Design Office for additional information and assistance.

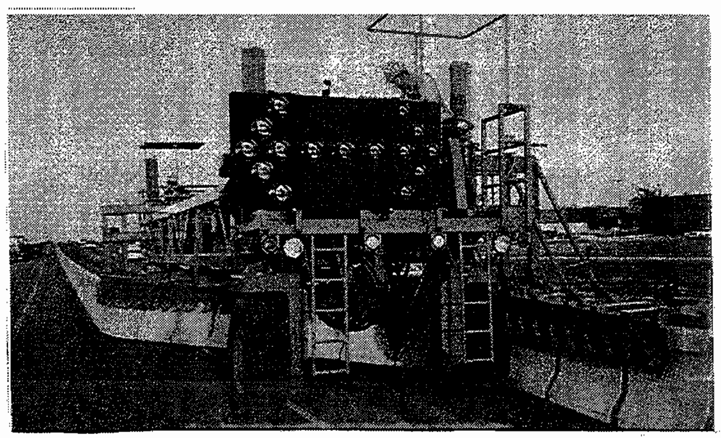


Figure 4.2.19 Moving of Quick Change Barrier

4.3 MEDIAN BARRIERS

4.3.1 SUMMARY BARRIER CHARACTERISTICS

Table 4.3.1 Summary of Median Barrier Characteristics

System	6 Cable	Box Beam	Steel Beam	Concrete	IBC MK7
Deflection	2.5 m	0.5 - 1.5m	0.3 - 0.6 m	0 m	0.5 m
Minimum free standing length	Refer to Chapter 3.0 Section 3.4.2				
Minimum length connected to rigid object	Refer to Chapter 3.0, Section 3.4.2				
Equivalent Capital Cost *	1	5	3	3	8
Equivalent Maintenance Cost *	3	3	2	1	4

* Equivalent costs are to be used as a guide only. Contact the Estimating Office for Actual costs.

For additional information refer to the appropriate section in this chapter.

4.3.2 6 CABLE (WOOD POST)

NOTE: This system, shown in Figure 4.3.1, is no longer approved for use on high speed facilities. The information below is for installations on low speed highways and for maintenance purposes for existing installations on provincial highways, which will be replaced when rehabilitation is scheduled.

DESIGN FEATURES

The system consists of 3 cables mounted on each side of 150 mm diameter wooden posts, and anchored by a one cubic metre concrete anchor block. The cables are installed on the post using a standard spacer plate and staples, or bracket. The posts are spaced at 3.6 metre intervals. For summary of barrier characteristics and features refer to TABLE 4.3.2.

TABLE 4.3.2
SUMMARY OF 6 CABLE BARRIER (WOOD POST) CHARACTERISTICS

deflection	- to 2.5 m
post spacing	- maximum 3.6 m
installation height	- 685 mm (top cable)
tension	- sag < 6.3 mm between posts
minimum length	- 46.8 m
maximum length*	- 305 m
minimum radii	- 250 m
placement	- medians > 9 m width slopes < 10:1
curb and gutter	- not to be used

* between anchor blocks

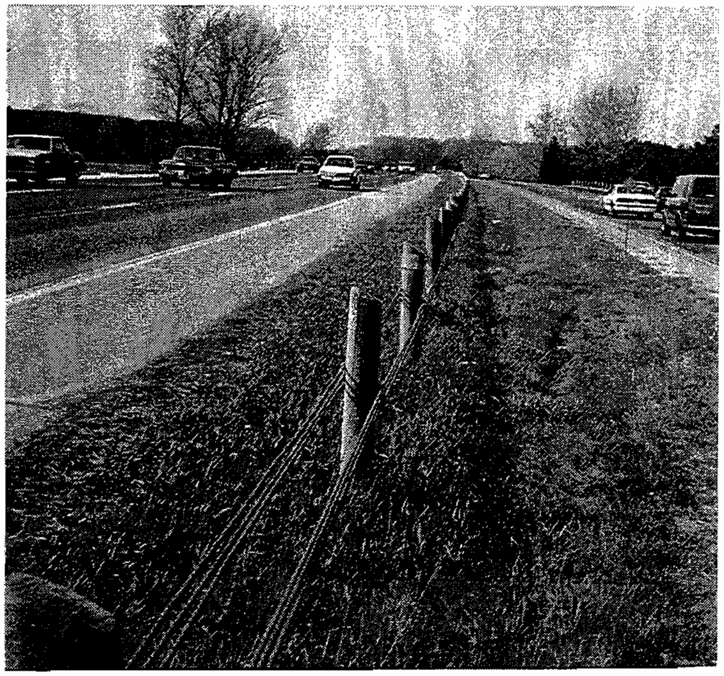


Figure 4.3.1 6 Cable Guide Rail (Wood Post)

PERFORMANCE (Six Cable Wood Posts)

On impact by an errant vehicle the posts hold the steel cables long enough to ensure that the steel cables are embedded in the vehicle. As the system deflects, the posts break away and the tensile strength of the cables resists and redirects the vehicle. The system will deflect laterally to approximately 2.5 m, depending on the severity of impact. The posts provide minimal lateral restraint.

The performance of the cable system is sensitive to mounting height and tension. In addition the surface adjacent to the system must have a consistent slope, to provide an even, predictable trajectory for the errant vehicle. If these parameters are not correct, the system may not perform as designed.

INSTALLATION (Six Cable on Wood Posts)

The 6 cable guide rail system was designed to be placed on medians with a width greater than 9 m, and on slopes 10:1 or flatter. The system may be used as a new median barrier installation only on low speed, low volume facilities, with a low concentration of commercial vehicles, because of its relatively narrow target area, high repair costs, and the extreme sensitivity to correct installation and vehicle type.

The median should preferably be a hard surface, to prevent rutting. A grassed median is acceptable, provided that the underlying soil structure is stable.

The mounting height of the top cable, measured at the face of the system, must be 685 mm. Proper tension results in a sag of 6.3 mm or less between posts.

To ensure that the barrier performs as designed, the post spacing must be 3.60 metres and with a minimum embedment depth of 1.2 metres, as shown on the OPS standard drawings. Cable splices are not to be less that 15 metres apart on any one cable and no more than one per panel.

Six Cable guide rail is not to be placed adjacent to curbs.

The minimum length of installation is 46.8 m with a maximum of 305 m between anchor blocks.

To maintain tension on the system during an impact, the minimum installation radius is 600 m and minimum vertical curvature K=15.

END TREATMENT (Six Cable on Wood Posts)

The 6 Cable guide rail system is anchored to a buried 1 cubic metre concrete anchor block at each end, and at a maximum 305 metre interval. The anchor block may be cubic or cylindrical. Since the end is not considered to be a hazard, flaring is not required.

STRUCTURE TREATMENT	Refer to
TRANSITIONS	3 Cable Guide Rail
MAINTENANCE	Section 4.2.2

4.3.3 6 CABLE STEEL POST (EXPERIMENTAL SYSTEM)

DESIGN FEATURES

This system, shown in Figure 4.3.2, consists of six cables in a vertical plane, retained in position by a formed nylon spacer, shown in Figure 4.3.3, clipped into a slotted, I section steel post. The posts are spaced at 4 m intervals and capped with reflective plastic marker caps. The system is anchored by standard 1 cubic metre concrete anchor blocks.

Although this system is currently experimental, it is performing well in trial installations, and is expected to become the standard cable guide rail system for median installations. The ideal use for this system may be as a temporary installation at locations where the median is 10 to 15 metres wide, lanes are to be added to the inside in approximately 10 to 15 years, does not meet the median warrant guide, (see Chapter 2, Section 2.10), but where an operational problem involving passenger cars has been identified. A Cost Benefit analysis, should be undertaken to determine if this barrier is suitable in the location, under review (see Chapter 2, Section 2.14).

Since the system is experimental the designer should consult with the Surveys and Design Office before including it on contracts, to ensure appropriateness of the installation and consistency of design, and to enable a monitoring system to be set up in conjunction with the Regional Traffic, and Traffic Management and Engineering Offices.

TABLE 4.3.3
SUMMARY OF 6 CABLE BARRIER (STEEL POST) CHARACTERISTICS

deflection	- to 2.5 m
post spacing	- maximum 4.0 m
installation height	- 685 mm (top cable)
tension	- sag < 6.3 mm between posts
minimum length	- 46.8 m
maximum length*	- 305 m
minimum radii	- 600 m
placement	- medians > 9 m width slopes < 10:1
curb and gutter	- not to be used

* between anchor blocks

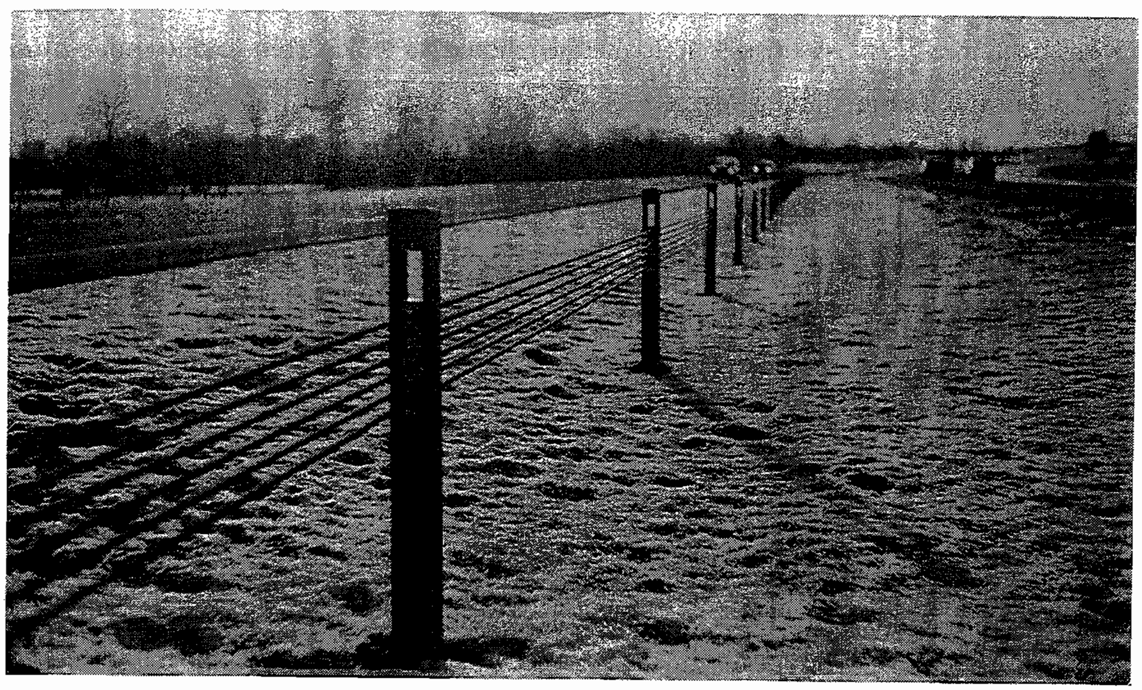


Figure 4.3.2 6 Cable Guide Rail on Steel Posts

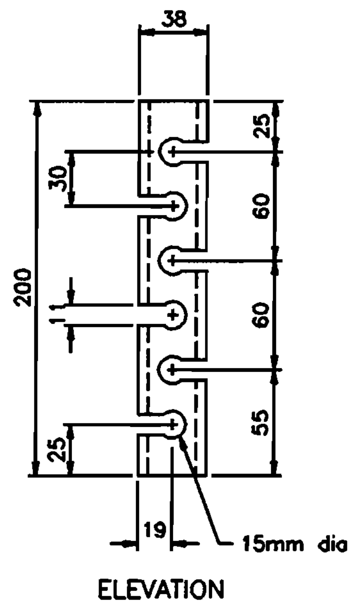


Figure 4.3.3 Nylon Spacer

PERFORMANCE (Six Cable on Steel Posts)

Optimum barrier performance depends on the proper mounting height of the cables. It is essential that this height be maintained for the full service life of the installation.

The six cables are all mounted in the same plane presenting a 150 mm target area, which is more than the 100 mm target for the six cable wood post design. Thus this system is less susceptible to under ride by modern, aerodynamically shaped vehicles. On impact, the cables are held in position long enough to ensure that they are embedded in the vehicle. As the system deflects, the weak post bends, or the slot shears, and the cable detaches from the posts. The tensile strength of the cables resists and re-directs the vehicle. The system will deflect laterally to approximately 2.5 metres, depending on the severity of impact.

INSTALLATION (Six Cable on Steel Posts)

The 6 cable guide rail system is designed to be placed on medians with a width greater than 9 m, and on slopes 10:1 or flatter. Slopes steeper than this should not be considered, as the breakpoint of the slope change causes errant vehicles to become airborne with an unpredictable trajectory. As a result, it is impossible to determine correct barrier location or mounting height.

The surface run-up to the guide rail may be earth. However, treated granular is preferred, since it is not as susceptible to rutting or erosion.

The mounting height of the top cable must be 685 mm. Proper tension results in a sag of 6.3 mm or less between posts. The first post after the anchor block has a ground mounted bracket to resist bending during tensioning. The orientation of the bracket is important.

Six Cable guide rail is not to be placed with curbs, since vehicle behaviour is unpredictable after contact. Where the placing of guide rail adjacent to curb is unavoidable, double steel beam guide rail with channel should be used. Refer to Section 2.7.3.

The minimum length of an installation is 46.8 m, with a maximum of 305 m between anchor blocks.

STRUCTURE TREATMENT	
	Refer to
TRANSITIONS	Roadside Barriers
	3 Cable Guide Rail
MAINTENANCE	Section 4.2.2

4.3.4 MEDIAN BOX BEAM BARRIER

DESIGN FEATURES

The median barrier, shown in Figure 4.3.5 , consists of a beam 5.474 m in length with a cross-section of 203.2 x 152.4 x 6 mm. These beam sections are slotted and are supported by I-section posts driven 900 mm into the pavement. The 125 x 150 x 5 mm thick steel plates are bolted onto the upper end of the I-section and fit into the slots in the bottom of the rail. The 41.7 kg per metre dead weight of the beam is the only force necessary to maintain this connection. The sections are then bolted into a continuous member by means of splice plates. A 6 mm plate is welded to the lower end, (below ground), of each I-section parallel to the rail's long axis. This plate assists in generating a uniform post impact failure. As a result of deflection properties, median installations are restricted to a minimum radius of 600 m.

TABLE 4.3.4
SUMMARY OF BOX BEAM MEDIAN BARRIER CHARACTERISTICS

deflection*	- 0.5 to 1.5 m
post spacing	- maximum 1.83 m
installation height	- 735 mm
minimum length	- 30.0 m
minimum radii	- 600 m
placement	- medians > 9 m width slopes < 10:1
curb and gutter	- only mountable type may be used

* refer to Table 4.3.5

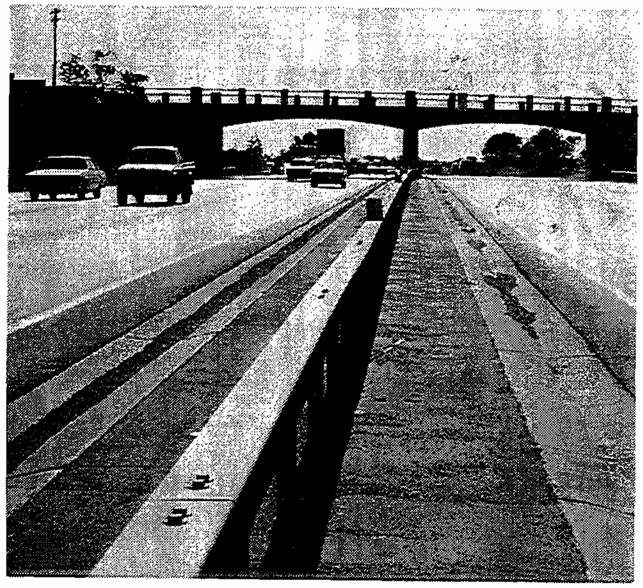


Figure 4.3.4 Box Beam Median Barrier
(203.2 x 152.4 mm)

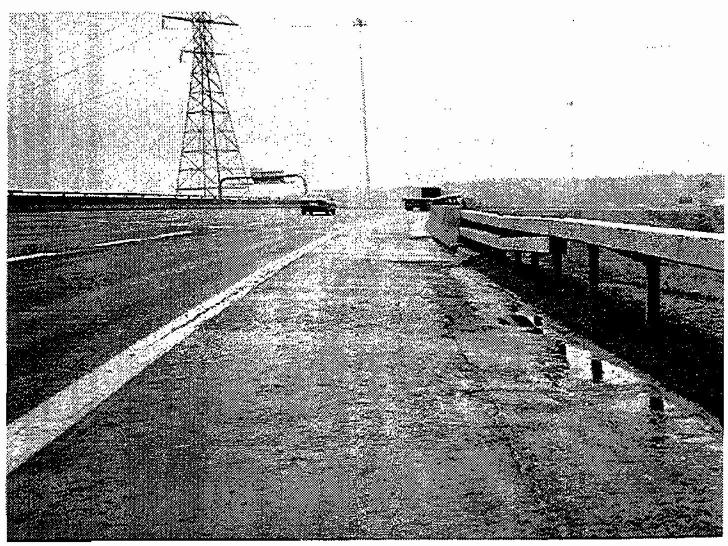


Figure 4.3.5 Double Beam Installation

PERFORMANCE (Median Box Beam)

Resistance in this system is achieved through a combination of bending and the tensile stiffness of the beam. When a vehicle hits the box beam assembly, the supporting steel posts are bent forward by the vehicle and "freed" from the beam.

While this system is often capable of restraining light commercial vehicles, it was not designed for this function. On roadways with heavy volumes of traffic and a significant portion of commercial vehicles, other barrier alternatives are more suitable.

On impact the vehicle tends to remain in contact with or very close to the beam throughout its horizontal exit trajectory. If the beam does deflect the vehicle back into the traffic, it is usually at a small angle. On occasion the vehicle will become wedged under the beam and slide until coming to a stop. This is also considered to be acceptable performance, however more damage will result.

The older beams may develop brittle fracture, which is exhibited by cracks developing in the underside at the paddle slots. The system must be examined periodically particularly after collisions, and the defective beams replaced.

As with all flexible systems, the system is sensitive to mounting height, and optimum performance depends on proper installation.

With 1.83 m post spacing the lateral deflection of the system does not exceed 1.5 m. Deflection of the median box beam system can be further reduced by adding a second beam. (See Figure 4.3.6, and Table 4.3.5.)

TABLE 4.3.5 BOX BEAM DEFLECTIONS

BOX BEAM GUIDE RAIL		
POST SPACING	DEFLECTION	
	SINGLE RAIL	DOUBLE RAIL
1.83 m	1.2 m - 1.5 m	----
0.9 m	1.0 m - 1.2 m	0.5 m

BARRIER INSTALLATION (Median Box Beam)

The use of box beam barrier median barrier is restricted to new facilities with posted speeds of less than 80 km/h. The system is ideally suited for low speed urban environments, since it is more compact and aesthetically appealling then most other systems. It may also be used as a roadside application. (Refer to Chapter 4, Section 4.2)

The barrier is installed in the centre of a median at least 4 m wide. The mounting height is 735 mm from ground level to top of the beam, measured at the face of the posts. It is essential that this height be maintained for the full service life of the installation.

Box Beam guide rail should not be placed adjacent to curb and gutter unless it is the fully mountable type. If barrier curbs cannot be avoided, steel beam guide rail with channel should be used. Refer also to Chapter 2.0, Section 2.7.3.

As a result of its deflection properties, and to ensure tension in the system is not lost when struck, median box beam installations are restricted to a minimum radius of 600 metres.

Existing median box beam barrier on high speed facilities should be replaced by another system if roadway work requires the removal or adjustment of the system for any contracts longer than 0.5 km.

END TREATMENT (Median Box Beam)

The end of the median box beam guide rail must be turned down and anchored to a concrete anchor block. When the median is wide enough the end should be flared away from traffic as much as possible.

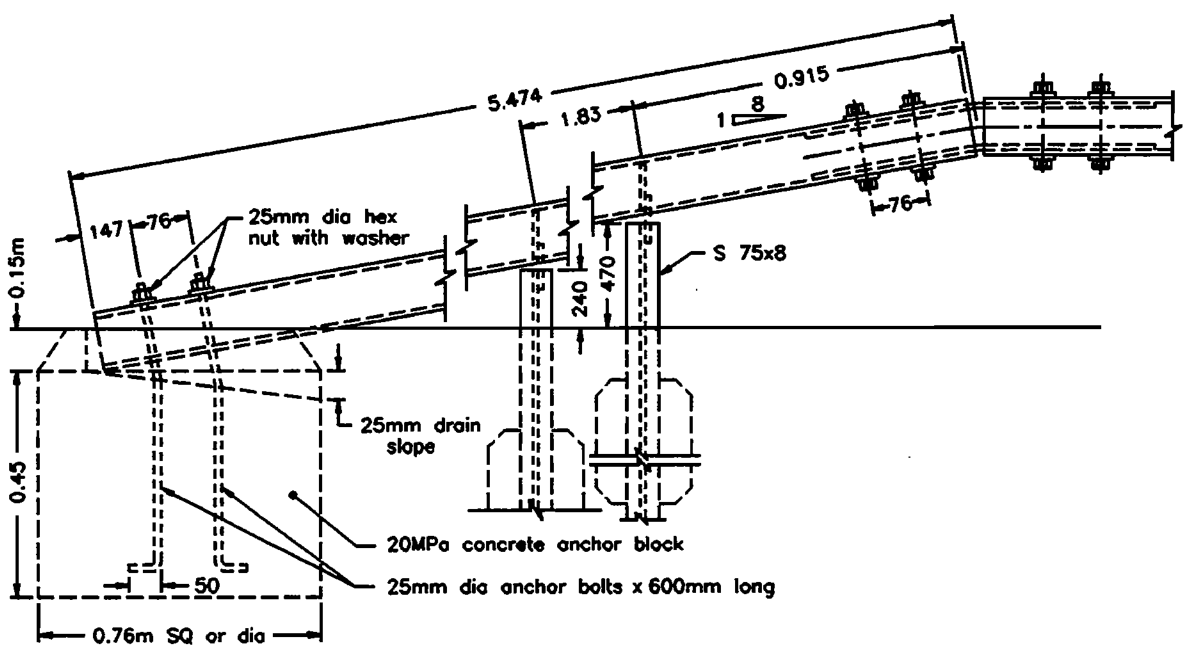


Figure 4.3.6 End Treatment Median Box Beam

STRUCTURES TREATMENT (Median Box Beam)

Approach treatments at structures are similar for both the shoulder and median barrier systems. On both installations, reduced post spacing and proper anchorage to the structure are necessary. Median installations are reinforced with a second beam at the approaches to structures.

At the leaving end of a structure only a proper anchorage connection to the parapet wall is necessary. Refer to the OPSD manual for additional details.

TRANSITIONS (Median Box Beam)

When transitioning from one system to another the design must allow for variations in deflection properties of each barrier. When transitioning to concrete barriers, designers should use the structure treatment given above. Median Box Beam systems are rarely transitioned to other systems. If this is required, the designer should allow for the deflection differences in the design, and contact the Surveys and Design Office if assistance is required.

MAINTENANCE (Median Box Beam)

Maintenance information is presented to make the designer aware of maintenance requirement. Refer to the Ministry maintenance manual for maintenance operating instructions. Refer also to Chapter 3.0, Section 3.3 for barrier selection, and maintenance considerations.

To ensure proper performance of the system the beam elements require inspection after each collision, checking a minimum of 3 beam elements on each side of the point of impact. This inspection should include checking the paddle slots for cracking, and the splice plate bolts for shearing and indications of severe rusting. Any cracked beam elements and sheared bolts must be replaced.

Damage to box beam barrier, regardless of its severity, usually requires immediate attention and repair. Bent posts are removed and new ones driven in with portable drop-hammers. Damaged sections of the beam are unbolted, replaced and reattached to the new posts.

A box beam median barrier is troublesome to maintain. To replace any damaged posts, long heavy rail sections must be removed, using mechanized equipment. Proper alignment of the post paddles and rail slots and reassembly of the tube splices are also difficult. An impacted box beam may also bend or even break at the mounting slots.

It is often difficult to install new posts in winter, due to frozen ground. This can result in the beam being unsupported at the correct mounting height for an extended period. Temporary legs may be attached to the beam to support it at the correct mounting height. These legs have the potential to become projectiles, but are less hazardous than leaving the beam unsupported.

Due to high maintenance costs and the requirement for repair even with minor hits, the box beam barrier should not be used on high volume roadways, or at high risk locations such as narrow medians, or small radius curves.

4.3.5 STEEL BEAM GUIDE RAIL

DESIGN FEATURES

Steel beam guide rail is a semi-rigid barrier installation which restrains and redirects vehicles by a combination of beam bending and tension, and the lateral restraint provided by the posts. The system is stiffened by the addition of a channel.

The two versions of median steel beam barriers are standard double rail with channel, (Figure 4.3.8), and double rail with double offset blocks and offset channel, Figure 4.3.9. The latter is used to prevent errant vehicles from striking conventional light poles and sign posts that are installed in the median.

The W-shaped steel beam rail is bolted to 190 x 190 mm wooden posts. The guide rail is offset from the posts by wooden blocks, minimizing pocketing and snagging. Refer to Table 4.3.6 for summary of steel beam characteristics. For additional, more detailed information refer to the remainder of this section, and to the drawings and specifications contained in the OPS manuals.

TABLE 4.3.6 SUMMARY OF STEEL BEAM BARRIER CHARACTERISTICS

deflection	- 0.3 to 0.9 m
post spacing	- maximum 1.90 m
installation height	- 610 mm centre
placement *	-
curb and gutter	- See Chapter 2, Section 2.7

* Placement in the median on minimum 10:1 slopes, or 6:1 provided it is offset a minimum of 4 metres from any surface breakpoint.

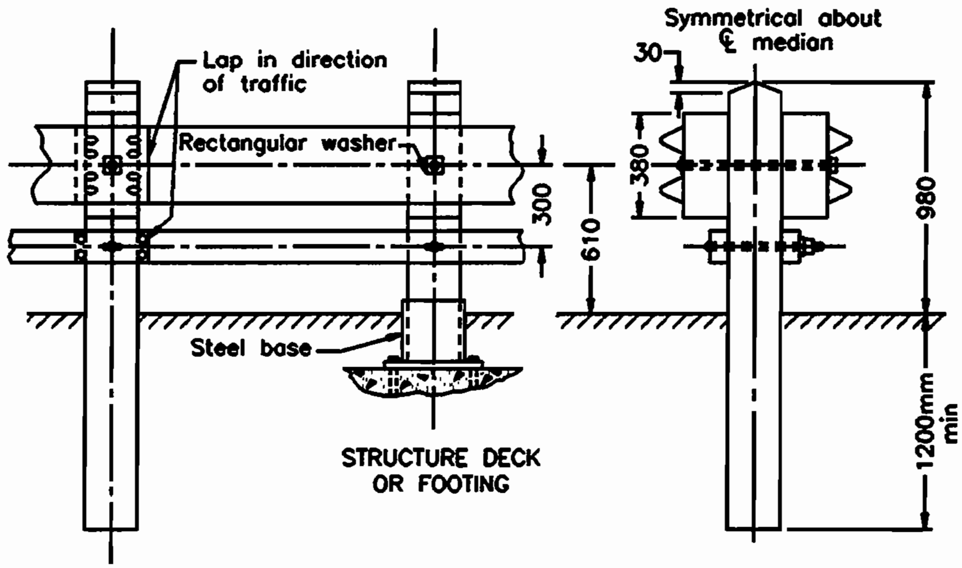


Figure 4.3.7 Steel Beam Median Guide Rail

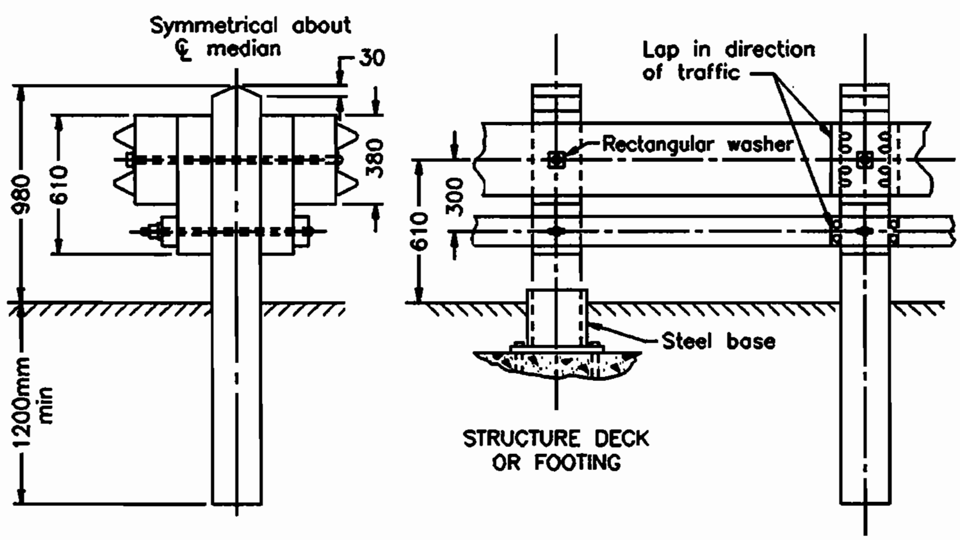


Figure 4.3.8 Steel Beam With Double Offset Blocks

PERFORMANCE (Median Steel Beam Guide Rail)

Steel beam median barriers are effective on high volume highways where the frequency of minor accidents is high, and where there is the possibility of major accidents. Vehicles striking the rail at a small angle and low speed are redirected at small exit angles with minor damage. At high speeds and large impact angles, however, vehicle damage on impact with this relatively rigid system may be severe. Damage to the system itself may be less severe than other, more flexible systems.

Optimum barrier performance depends on the proper mounting height of the beam. It is essential that this height is maintained for the full service life of the installations.

Excessive mounting heights allow the front of a vehicle to get under the offset beam and snag on the heavy posts, causing spinout and possible vehicle rollover. Mounting heights that are too low place the centre of gravity of a vehicle above the barrier rail. Upon impact an overturning moment is generated which may cause the vehicle to roll over the guide rail. Poor quality posts, shallow embedment, or lack of support behind the post may cause the barrier to lean. If the beam fails to engage the vehicle, this can result in override of the system, or rollover. When steel beam guide with inadequate stiffness is installed with a curb, pickups and heavier passenger cars will deflect the system excessively, and compression and subsequent decompression of the vehicle suspension system, may result in vaulting over the guide rail. It is therefore desirable to design the system without curb. If curb is required, however, only the mountable type should be used.

Dynamic tests show that a post spacing of 1.9 metres provides optimum resistance and, together with the channel, allows a deflection of about 0.6 m. Lesser deflections of 0.3 m to 0.6 metres can be achieved by reducing the post spacing and if required, by adding another beam element.

BARRIER INSTALLATION (Median Steel Beam Guide Rail)

The two double faced versions of the steel beam guide rail system are available for use in medians. The double beam with channel is the standard treatment.

The double beam with offset channel and double offset blocks is used to provide space in the median for light poles and sign posts, and also to provide some measure of protection from these hazards. To increase the rigidity and thus a reduction in deflection, the post spacings are reduced to 950 mm for a distance of 7.6 m adjacent to the pole or sign location. However, this method does not satisfy the need for a minimum lateral distance for deflection of 0.6 m between the rail and the pole, and it should only be used as a last resort. The steel beam guide rail can be connected to concrete footings in the shape of concrete barriers for these items.

END TREATMENTS (Median Steel Beam Guide Rail)

TRANSITIONS

Refer to roadside steel beam guide rail section 4.2.4.

MAINTENANCE

4.3.6 STANDARD CONCRETE BARRIER, F SHAPE

NOTE: FOR PRECAST CONCRETE BARRIERS REFER TO CHAPTER 4, SECTION 4.2.7

The basic concept of the concrete median barrier was developed in New Jersey. The shape and height were determined largely by trial and error. Subsequent designs established the height at 825 mm, which was high enough to restrain most vehicles but not high enough to obscure the driver's view and it allowed for 75 mm asphalt overlay adjacent to the barrier. Recently the New Jersey shape was modified and the Ministry has adopted a variation called the F shape. F Shape does not refer to the shape of the barrier, merely the crash test designation. This shape has been crash tested and found to be less likely to cause rollovers of cars at the bottom of the design vehicle range.

DESIGN FEATURES

The concrete median barrier, Figure 4.3.9, and Figure 4.3.10 consists basically of three sections:

1) a 75 mm vertical base section which is buried in the surrounding pavement structure.
2) a 55 degree sloped section, rising 250 mm above pavement,
3) an upper vertical section sloping upward at the rate of 10:1, bringing the barrier to its full height of 825 mm from the top of the pavement.

TABLE 4.3.7
SUMMARY OF STANDARD CONCRETE BARRIER CHARACTERISTICS

deflection	- 0.00
height	- 825 mm
placement	- paved slopes < 10:1
curb and gutter	- not to be used

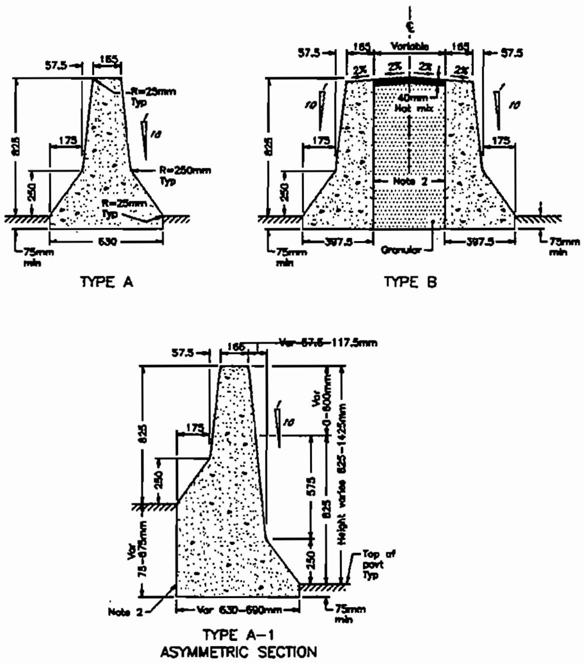


Figure 4.3.9 Concrete Barrier

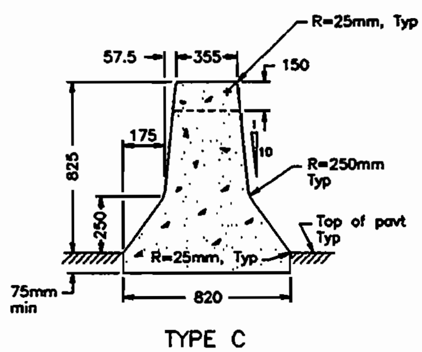


Figure 4.3.10 "C" Type Concrete Barrier

PERFORMANCE (Concrete Barrier)

In order for the barrier design to work as intended, the vehicle must not be clear of the ground on impact. If the vehicle is off of the ground, the effect may be similar to striking an ordinary concrete wall, and the impact will be extremely severe. With impacts up to a 15 degree angle and speeds of 100 km/h respectively, a vehicle mounts the sloped portion of the barrier, the vehicle suspension is compressed; the wheels are turned toward the barrier, and the vehicle slides along the barrier face. During this phase, the upward sloped face tends to make the vehicle rotate about its longitudinal axis, converting some of the lateral kinetic energy to the vertical axis. In this way, the energy is absorbed with minimal damage to the vehicle and barrier. The effect of passenger deceleration will result in little or no injuries, and the vehicle should remain within its own lane after impact.

The concrete barrier may re-direct or contain heavy vehicles, but it is not designed for this purpose. Refer to Chapter 4.3.8.

To decrease friction between the tires and the concrete barrier, (and thus the height that a vehicle may ride up on the face of the barrier) the barrier should be smooth (with no brushing after slip forming). Vehicles often escape damage entirely on low angle hits.

The standard concrete barrier is considered to be operationally equivalent to the IBC MK-7 barrier. From an operational standpoint, the main difference between the two is in the method of energy dissipation. The IBC system dissipates energy when the barrier is crushed, and when its mass is shifted.

BARRIER INSTALLATION (Concrete Barrier)

Refer also to the OPS drawings and specifications.

In order for the barrier to perform as designed, no curbs, gutters or ditches are allowed between the barrier and the driving lanes, except on structures where sidewalks are required. The area directly in front of the barrier must be paved, at a maximum slope of 10:1. Pavement is required to maintain a smooth surface adjacent to the barrier. Granular surfaces are susceptible to erosion and rutting, (creating irregular approach surfaces), and possible barrier instability.

Dynamic tests have shown that the probability of high speed high angle impacts occurring is very low. Since concrete performs well at high speed, low angle impacts, it is therefore the preferred barrier at locations such as freeways with relatively narrow shoulders. A concrete median barrier should not be located more than 4.0 m from the edge of a driving lane since the cost of paving the shoulder becomes excessive, and angle of impact may increase at greater offsets. At large angles, the barrier still contains the vehicle, but injuries and damage may increase. **Contrary to expectations, the incidence of high angle hits does not increase significantly on multi-lane facilities, and there are therefore no restrictions on the use of concrete barriers on these roadways.**

The concrete median barrier is also well suited to locations where there is a grade differential between opposing lanes. In these instances, an asymmetric barrier section, (see Figure 4.3.11) is used up to a grade differential of 600 millimetres. With the use of a concrete barrier on a stepped median additional shoulder width is gained, as opposed to utilizing this width to accommodate a sloped surface for other guide rail systems. With a grade differential greater than 600 mm, an F shape retaining wall structure should be designed and installed.

When type B half sections with granular infill are being used, care must be taken to prevent moisture infiltration. This and a substantial grade differential between the two halves may cause barrier failure. Consult the Structural and Foundation Section. Refer to Figure 4.3.9.

When traditional median lighting is required, the standard " C" type barrier, must be used. See Figure 4.3.10.

The warrants for placing a concrete median barrier are the same as for other median guide rail systems. These warrants are shown in Chapter 2, Section 2.10.

END TREATMENT (Concrete Barrier)

Refer also to Chapter 2, Section 2.4.1

The approach end of the concrete barrier must truncated and protected with an approved end treatment or energy attenuator. Alternatively the turned down end section of the concrete barrier consists of a 10 m transition from the 825 mm height down to a 75 mm height, using a tapered section, shown in Figure 4.3.12. This end treatment may cause vehicle vaulting and rollover, and thus should only be used if the end can be located outside of the clear zone. Refer to Chapter 2.

TRANSITIONS (Concrete Barrier)

Transition to a concrete median barrier system should only occur with compatible systems. The IBC barriers, steel beam guide rail, and box beam are the only guide rail systems that may abut a concrete barrier. Box beam and steel beam guide rail must use reduced post spacing and additional beam elements. Refer to "Connection to Structure" of the various systems, shown in Section 4.2.

Regardless of the barrier systems used, the designer must adhere to the principle of allowing for the deflection characteristics of the two barrier systems.

Refer also to the appropriate design standards contained in the OPSD manual.

MAINTENANCE (Concrete Barrier)

The ministry's experience with the concrete barrier system, as well as the experience of other authorities, indicates that the system virtually eliminates maintenance costs. Additional savings and increased safety are realized, since the need for repair crews on the highway's shoulders is greatly decreased.

Snow accumulation can affect the operation of the barrier, however, and therefore should be removed as soon as practical to ensure proper performance of the barrier.

For detailed maintenance operations refer to the ministry's Maintenance Manual.

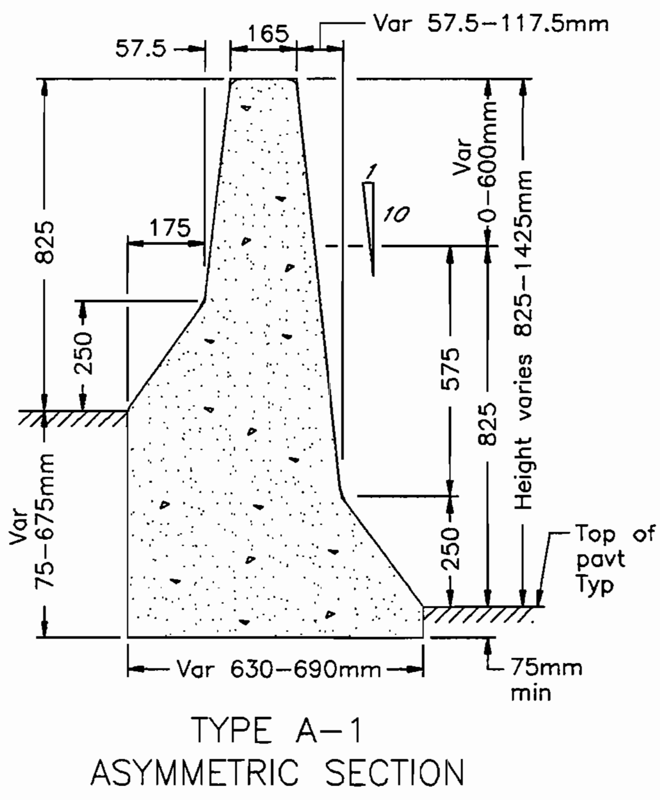


Figure 4.3.11 Asymmetric Barrier Section

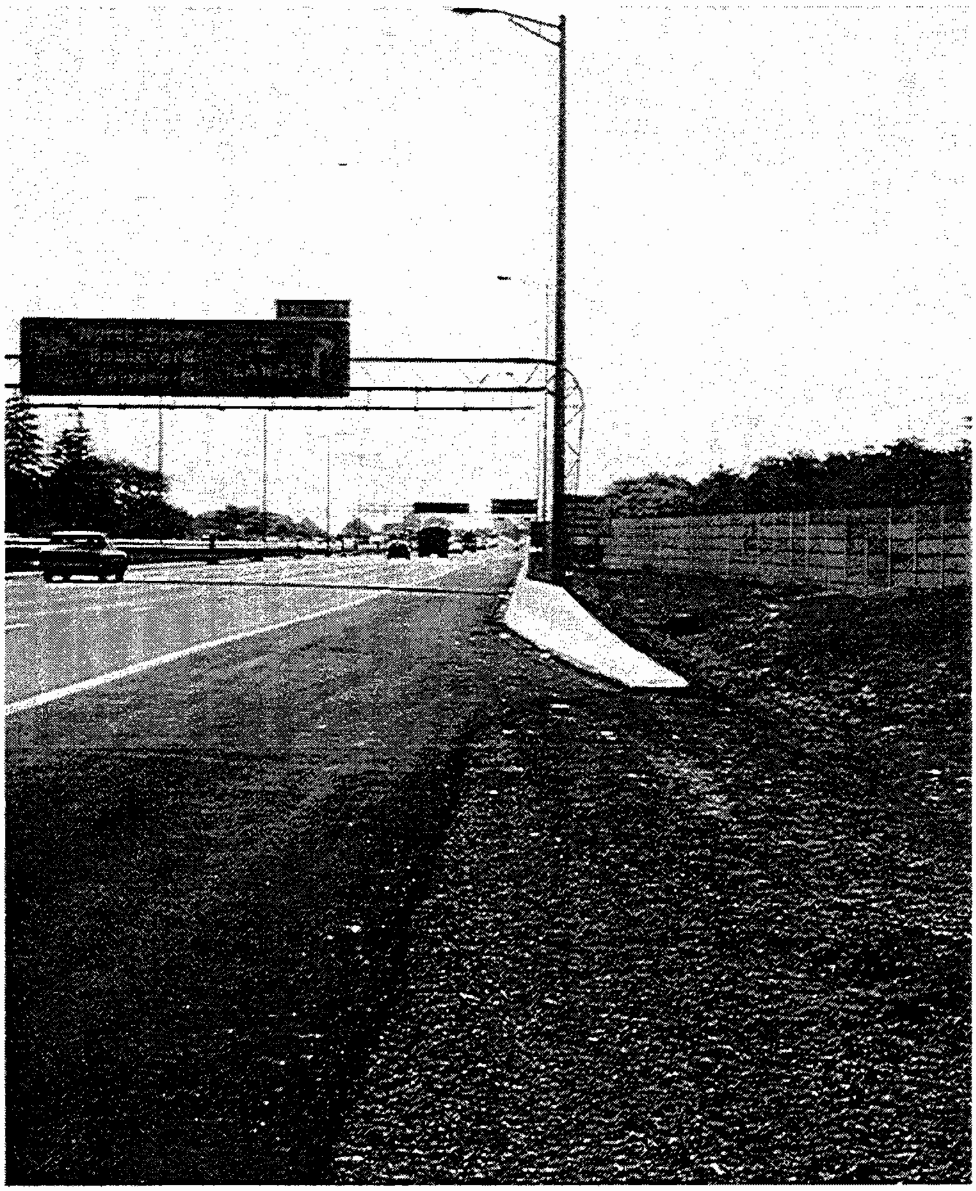


Figure 4.3.12 Tapered End Treatment, Permanent Installation

Note: This treatment should only be used where the entire turned down end will be beyond the design clear zone.

4.3.7 IBC BARRIER (MK-7)

DESIGN FEATURES

The IBC Mark 7 barrier, shown in Figure 4.3.13, is a continuous, granular filled steel bin design, which absorbs energy and restrains errant vehicles by a combination of barrier movement, elastic deformation of the steel panels and displacement of the fill.

The barrier components are made of galvanized, or plastic coated steel for colour and added weather protection. This system is covered with a lid and can be filled with either sand or gravel. The open bottom design is free draining.

The IBC Barrier is preformed, pre-drilled and bolted together on the site, with the use of jigs. Each section is 3 m long and is joined by section bulkheads, which separate each bin section. All sections are filled with granular material. Lids are added to complete the barrier after filling operations. Table 4.3.8 summarizes the major characteristics of the barrier system.

TABLE 4.3.8
SUMMARY OF IBC MK-7 BARRIER CHARACTERISTICS

deflection	- 0.5 m
height	- 1070 mm
minimum length	- 30.0 m
placement	- roadside shoulder or slopes < 10:1
curb and gutter	- not to be used

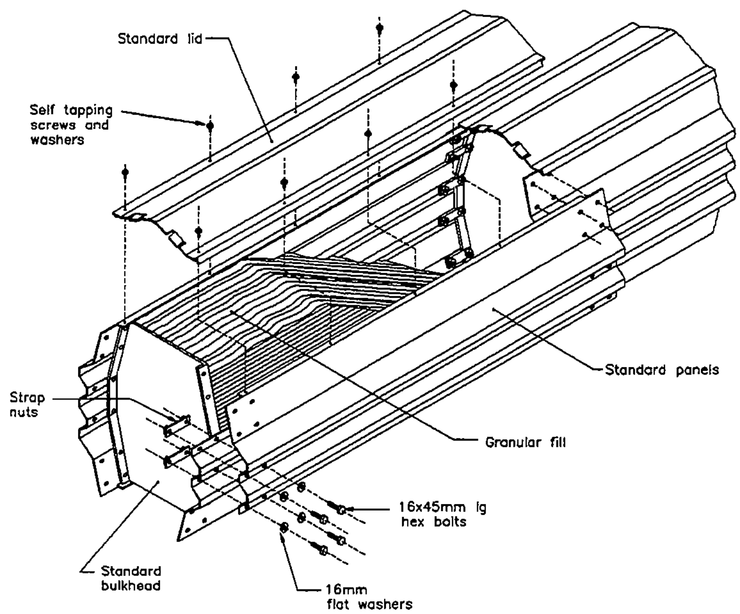


Figure 4.3.13 IBC Barrier

PERFORMANCE (IBC MK7 Barrier)

When a vehicle hits the barrier assembly, the entire barrier moves laterally to absorb the impact. The steel bins bend, the lids are jarred loose, and the sand fill is displaced, depending on the severity of the impact. The vehicle is re-directed at a shallow angle.

This barrier has been proven to successfully restrain cars, and light trucks. The ministry considers the system to be operationally equivalent to the standard F shape concrete barrier. From an operational viewpoint the difference is that concrete dissipates energy by raising mass vertically, and the IBC dissipates by crushing of the metal, and the lateral shifting of the barrier mass.

The vehicle re-direction is smooth, and the vehicle remains on the ground. This system may re-direct or contain heavy vehicles, but it is not designed for that purpose. See Sections 4.8 and 4.9 for high performance barriers.

Even minor hits cause some damage to the system but, the barrier remains fully operational and will continue to provide protection after all but the most severe collision. Vehicular damage is evident even at shallow angle impacts.

BARRIER INSTALLATION (IBC MK7 Barrier)

The use of permanent IBC barriers is restricted to locations where shoulders adjacent to the barrier are 3 metres wide or wider. As well the barrier must not be installed on or adjacent to any raised or dropped surface, such as curbs or islands, since the barrier is designed to shift laterally on impact.

The base required for barrier installation, can be any compacted surface such as concrete, asphalt or gravel. An earth or sod base is also acceptable on the recommendation of the Geotechnical Section. The main concern here is that the sand filled barrier may settle into unstable base materials. Since this barrier is designed to move as part of its energy absorbing characteristics, it requires a slip plane surface. If the barrier settles into the base, it will therefore not operate as designed. Similarly, the barrier must not be wedged between layers of asphalt, since it again can not perform properly.

The IBC MK7 system minimizes headlight glare due to its overall height.

Highway illumination poles, overhead sign supports, bridge piers, drainage, etc., can be readily located within the barrier system, using Ministry approved special assemblies.

The barrier is also suited for wide median applications where a history of vehicle crossing exists, and where the system can be installed without major reconstruction of the median. A cost benefit analysis should be performed prior to selecting this design.

This barrier can be used as an alternate to the pre-cast concrete barriers in construction zones, where deflections are critical. It may also be used in construction staging to taper 3 lanes of traffic into 2 lanes in the initial stages. It can be disassembled and relocated to its permanent location upon the 3 lane continuation, or be stored for future use as required.

TRANSITIONS (IBC MK7 Barrier)

The transition sections between the Concrete Median Barrier and the IBC, require a specially designed galvanized steel form, bolted and filled with concrete, to be poured in place. The form is then removed and salvaged.

Box Beam and Steel Beam transitions also require specially designed galvanized steel sections, bolted in place, with reinforced channels added to each "W" beam section.

The design principle required in each transition section allows for a gradual increase in stiffness and a transition in physical shape. When transitioning from a flexible barrier to the more rigid IBC barrier, the transition section should therefore be stronger than the flexible barrier and weaker than the IBC barrier. The same principle applies when transitioning from the IBC to a concrete structure.

The Surveys and Design Office must approve all transition or other special assemblies which are not depicted on the standard drawings.

STRUCTURES CONNECTION (IBC MK7 Barrier)

Special section components have been designed to provide a safe transition from the IBC barrier to a concrete structure. This section is made stronger than the IBC bin sections by the additional rib reinforcement which is bolted to both the structure and the IBC. The section is also filled with either sand or gravel.

END TREATMENT (IBC MK7 Barrier)

The end of the IBC barrier system is designed as a bullet nose section, which is secured to the ground using concrete end blocks. These sections are also filled with sand or gravel, but this treatment is not considered to be crashworthy.

Approach end terminal units must be protected by an approved end treatment or energy attenuation system. These include the GREAT system, or crash cushions such as the CIAS, or inertial barrier modules. As with other systems, the desired method is to terminate the barrier beyond the clear zone. Refer to Chapter 2, section 2.2 for clear zone offsets.

MAINTENANCE (IBC MK7 Barrier)

Damage to the barrier by an errant vehicle can be repaired in various ways, depending on the severity of the impact.

1. Minor damage to the surface of the galvanized panels can be repainted to prevent rusting.
2. Bent panels can be patched or covered with other panels which are bolted over top of the damaged ones.
3. Sections requiring extensive repairs have to be dismantled after the sand has been removed. The section is then reshaped and the damaged panels and bulkheads replaced, refilled with sand and completed, by adding the lid.

Ministry experience with the IBC system has shown that it performs well as a median barrier. However the maintenance costs were found to be high when the system is close to the traffic lanes. This is the main reason new usage of the barrier is restricted to sites that have a minimum offset of 3 metres to the barrier.

IBC barriers require specialized equipment during maintenance operations which adds to their overall cost.

The sides of the barrier are wider than the base, which makes mechanical removal of debris difficult. As well, the drainage openings in the side of the barrier have a tendency to collect debris, and snow plow operations may plug the drainage openings, leading to potential icing or flooding problems.

For detailed maintenance operating instructions, refer to the ministry Maintenance Manual.

4.3.8 ONTARIO TALL WALL CONCRETE BARRIER

DESIGN FEATURES

The Ontario Tall Wall concrete barrier, is a high performance barrier that is similar to the standard concrete barrier. The major differences are:

- an increase in height to 1050 mm above the pavement surface;
- increased width of the top;
- a wider base increased as a result of the height increase;
- an increase in the strength of the concrete to 35 Mpa; and
- the use of 100% crushed aggregate.

Refer to Figure 4.3.14 for design details, and TABLE 4.3.9 for a summary of barrier characteristics.

TABLE 4.3.9
SUMMARY OF ONTARIO TALL WALL CONCRETE BARRIER CHARACTERISTICS

deflection	- 0.00
height	- 1050 mm
minimum length	- 30.0 m
placement	- paved median shoulders
curb and gutter	- not to be used

Refer to Section 4.3.6, which outlines the standard concrete barrier, and to the appropriate OPS drawings and specifications for additional information.

BARRIER PERFORMANCE (Ontario Tall Wall Barrier)

The height of this barrier system effectively minimizes head light glare.

This barrier is one of only two barriers that are designed to restrain heavy commercial vehicles. The Tall Wall has demonstrated this ability under crash test conditions and performed well in over 30 tractor-trailer documented hits on the New Jersey Turnpike.

In the crash test with a 36,000 kg tractor trailer travelling at 80 km/h, the barrier successfully contained and re-directed the tractor vehicle. Although the trailer rolled over the barrier, this was attributed to the trailer's poor condition, and not related to the impact performance of the barrier.

The barrier maintained its structural integrity and sustained only cosmetic damage. There was no lateral movement of the barrier, and no debris or detached elements from the barrier which could cause hazards to the impacting vehicle or adjacent traffic. The vehicle sustained severe damage, but the passenger compartment maintained its integrity with acceptable deformation and no intrusion. The vehicle did not exit from the barrier, indicating minimal potential for intrusion into adjacent traffic lanes.

BARRIER INSTALLATION (Ontario Tall Wall)
Refer to Chapter 2, Section 2.10.2 for policy regarding installation of this barrier.

END TREATMENT	Refer to Section 4.3.6
TRANSITIONS	Standard Concrete Barrier -
STRUCTURE CONNECTION	F Shape
MAINTENANCE	For additional information

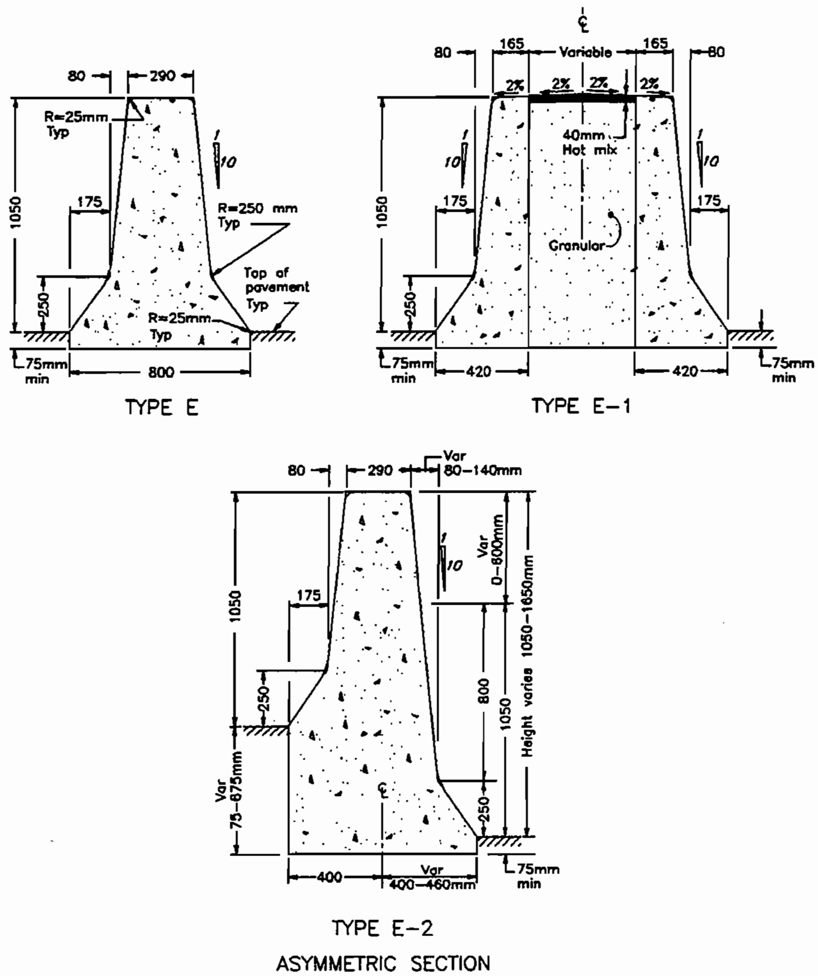


Figure 4.3.14 Ontario Tall Wall

4.3.9 IBC MK7-HV

DESIGN FEATURES

The MARK 7HV, an experimental high performance barrier, is identical to the MARK 7 except that it uses different fill. In place of the loose sand or stone, the Mark 7HV utilizes a cement stabilized fill. The stabilized fill, which has a strength of approximately 7 Mpa, is placed on a 75 mm sand cushion, which acts as a bond breaker, enabling the barrier to shift under severe impact.

The barrier is classed as an experimental system, and thus requires that the Surveys and Design Office confirm the appropriateness of selection to ensure consistency of design, and the implementation of a monitoring program in conjunction with Traffic Management and Engineering and the Regional Traffic Sections.

TABLE 4.3.10
SUMMARY OF IBC MK7-HV BARRIER CHARACTERISTICS

deflection	- 0.175 m
height	- 1070 mm
minimum length	- 30.0
placement	- median slopes less than 10:1
curb and gutter	- not to be used

BARRIER PERFORMANCE (IBC MK7 HV Barrier)

This barrier is one of two high performance barriers which are considered to be capable of restraining heavy vehicles. The IBC mark 7HV has successfully demonstrated this ability in crash tests, while still meeting the safety criteria for smaller vehicles.

In the crash test with a 36,000 kg tractor trailer the barrier successfully contained and re-directed the tractor trailer. The barrier received only minor damages with permanent lateral deflection of approximately 175 mm. The tractor trailer sustained severe damages, but there was no deformation or intrusion into the cab. The vehicle travelled along the barrier after impact, indicating minimal potential for intrusion into adjacent traffic. The vehicle remained upright throughout the test, although it exhibited a considerable amount of roll against the barrier.

Refer to Section 4.3.7, for **end treatment, structure connection,** and **maintenance** information on IBC barrier systems.
Refer to Chapter 2.0, Section 2.10.2 for policy on the use of this barrier system.

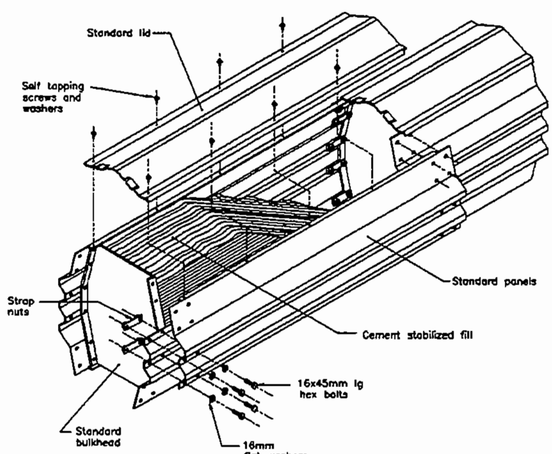


Figure 4.3.15 IBC MARK 7-HV

DETAILED TABLE OF CONTENTS

5.1 INTRODUCTION

End Treatments and crash cushions have been designed and tested for vehicles up to 2000 kg. For heavier vehicles such as large trucks they will not perform as designed. Where high performance barriers are warranted, the ends of the barriers should therefore be constructed beyond the clear zone whenever possible or terminated so as to be shielded. Refer to chapter 2, Section 2.4 and Chapter 3, Section 3.5 for additional details on end treatments and energy attenuators.

END TREATMENTS

In this manual, end treatments are defined as designed modifications at the end of roadside or median barriers. Specific end treatment requirements for each individual system are described under the appropriate headings in Chapter 4, Sections 4.2 and 4.3.

An untreated end of a roadside barrier is extremely hazardous if hit by a vehicle. An end treatment must therefore be installed if the barrier terminates within the clear zone, (see Section 2.2), or where it is likely to be hit head on by an errant vehicle. The end treatment, however, is not included in the calculated length of need of the guide rail system. See Chapter 3, Section 3.4.2.

The following end treatments are approved for use on provincial roadways by the Ministry.

Flared and Turned Down Ends
GREAT
TREND
CAT
Eccentric Loader
Extruder

There are a limited number of other types of end treatments presently installed on provincial highways, such as Oklahoma Turned Down End, Sentre, and BCT.

These installations are experimental, and should not be removed during re-construction projects without first consulting with the Surveys and Design Office.

CRASH CUSHIONS

Crash cushions are protective devices that prevent errant vehicles from striking fixed objects. This is accomplished by gradually decelerating a vehicle to a safe stop for head on impacts or, in most cases, by directing the vehicle away from the hazard during side impacts. This is accomplished by crushing of some material and the transfer of momentum within a relatively short distance.

Crash cushions are used at locations where fixed objects cannot be removed, relocated, or made breakaway, and cannot be adequately shielded by a longitudinal barrier. Some crash cushions placed across expansion joints may require modification. The Surveys and Design Office should be contacted for assistance.

The following crash cushions are approved for use on provincial roadways by the Ministry.

GREAT
CAT
HI-DRO/HI-DRI/HI-DRO CELL CLUSTER
CIAS
Inertial Barrier Modules

ARRESTORS

Arrestors are devices which stop out of control vehicles, primarily by friction. There are two types of ministry approved arrestors, however they are both experimental. Designers should contact the Surveys and Design Office for details and applications. The two devices are:

Dragnet
Truck Arrestor Bed

5.1.1 SUMMARY END TREATMENTS and CRASH CUSHIONS

Table 5.1.1 Summary of End Treatments and Crash Cushions

End Treatment Energy Attenuator	System Length (m)	Flare Offset (m)	Hazard Width (m)	Shoulder End Treatment				Median Approach Treatment or Gore Areas		Comments
				APPROACH		LEAVING				
				1-WAY	2-WAY	1-WAY	2-WAY	1-WAY	2-WAY	
Turned Down										Widening Req.
SBGR	15.24	1.37		X[a]	X[a]	X[a & f]	X[a]			Widening Req.
Concrete	10	1.50		X[a]	X[a]	X[a]	X			Widening Req.
Eccentric Loader	7.6	1.22		X	X		X			
Extruder	15.24	0		X	X		X			
TREND	6.6	0		X[b]	X[b]		X[b]			
CAT	9.5	0	0.6 - 5.0	X[c]	X[c]		X[c]	X[d]	X[d]	See Note g
GREAT	2-9	0	0.6-1.5	X[b]	X[b]			X[d]	X[d]	
GREAT (Temporary)	3.6 or 6.3	0	0.6-1.5	X[b]	X[b]		X[b]	X[d]		X[d]
C.I.A.S.	8.54	0.5	0.6-2.75					X[d]	X[d]	
Hi-Dro	1-9	0	1-2.75					X[d]	X[d]	Environmental Considerations
Hi-Dri	1-9	0	1-2.75					X[d]	X[d]	
Inertia Modules	3-9	0	1-5					X[e]	X[e]	

a- For all design speeds the turned down portion of end treatment shall be located beyond the Clear Zone offset.
b- In length restricted areas adjacent to structures, and as an end treatment for shoulder installations of concrete barrier.
c- Only where flaring of shoulder installations of SBGR cannot be constructed cost effectively.
d- Proper flaring of adjoining guide rail is required when hazard is larger or smaller than attenuator.
e- Requires a double row of modules as a minimum treatment.
f- Also used as core/collector transfer lane leaving end treatment.
g- Transition in barrier stability required at rigid obstacles.

5.1.2 SUMMARY TRANSITION TREATMENTS

Table 5.1.2 Transition Treatments

Type	System Length (m)	Flare Offset (m)	Transition Cable to SBGR			
			CABLE TO SBGR		SBGR TO CABLE	
			APPROACH		LEAVING	
			1-WAY	2-WAY	1-WAY	2-WAY
Eccentric Loader	7.62	1.22	X[a]	X[a]		X[a]
SBGR Upright End	1.0	0 or 3	X[b]	X[b]	X[c]	X[b]

a- 1.22 embankment required.

b- 3.0 metre embankment widening is required on approach transition treatment.

c- Flare not required on leaving end and not to be used within hazard clear zone.

5.2 END TREATMENTS

For selection of an End Treatment appropriate for a specific guide rail or barrier, refer to Chapter 3, Section 3.5.1.

5.2.1 FLARED AND TURNED DOWN ENDS

CABLE TURNED DOWN END

The end of a cable guide rail system is simply turned down and fastened to a buried concrete anchor block, with no offset flare. Since this is a weak post system, there is no danger of spearing or vaulting type accidents at the end, although snagging may occur. No treatment to protect the end is required. See Figure 5.2.1

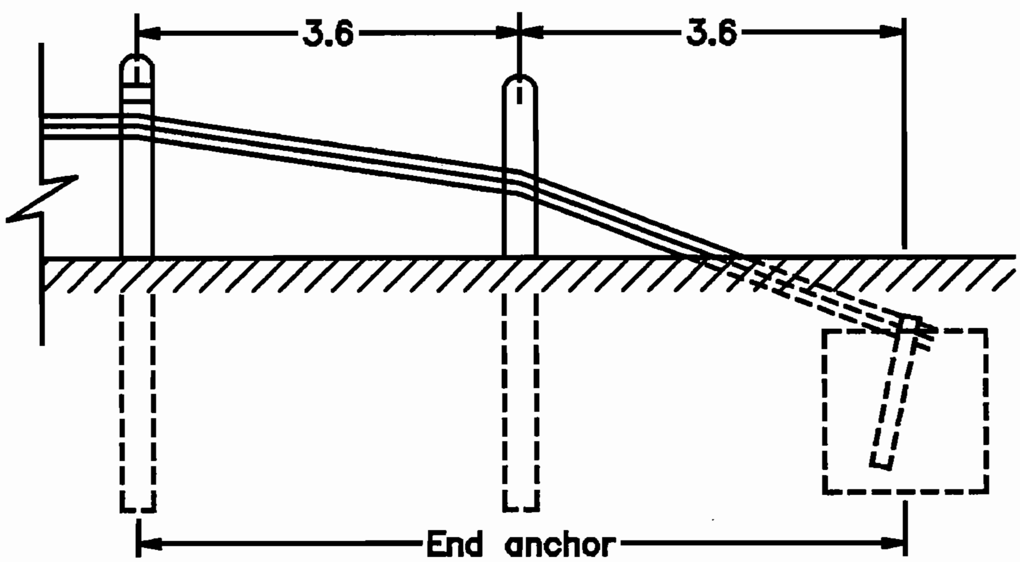


Figure 5.2.1 Turned Down End for Cable Guide Rail

Refer to the OPS drawings for additional details

BOX BEAM FLARED AND TURNED DOWN END

The end of the box beam guide rail is flared away from the shoulder a minimum distance of 1.2 metres, and fastened to a concrete anchor block. This flare requires that the embankment be widened to accommodate the offset. Turning down the end avoids spearing type accidents. Vaulting may occur, but is unlikely with a weak post system. No other treatment is needed to protect the end of the box beam guide rail. The designer should be aware that the 1.2 m flare is only a minimum and should be increased if possible. The rate of change of the flare, however, should not be increased. The designer should ensure that the embankment widening is included in the design cross-sections.

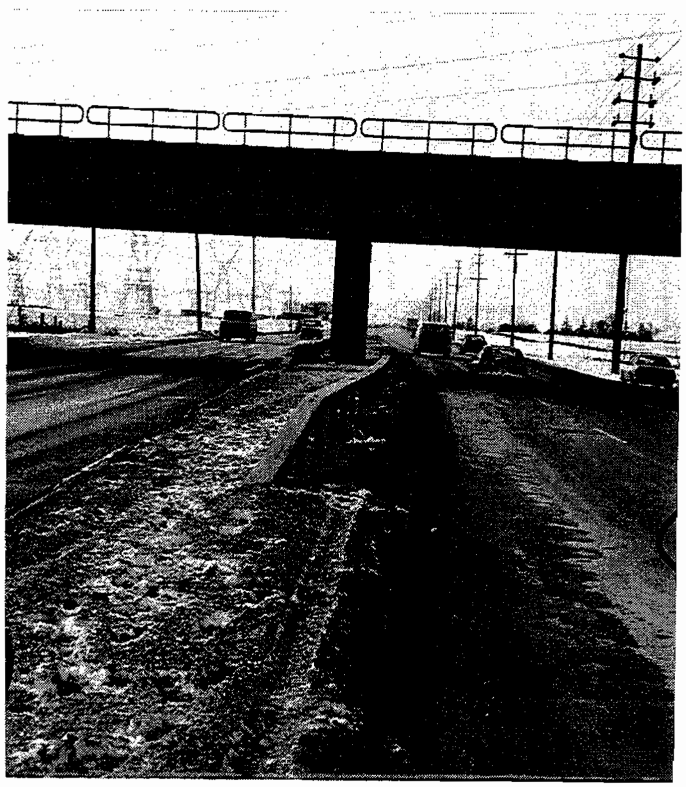


Figure 5.2.2 Flared and Turned Down End for Box Beam Guide Rail

Refer to the OPS drawings for additional details.

STEEL BEAM FLARED AND TURNED DOWN END

Flared and turned down ends of steel beam guide rail, consisting of 4 standard rail lengths, is to be used only where the end is installed beyond the clear zone, or buried in a cut backslope. Refer to Section 2.2. The end is flared 1.37 metres and buried, and requires that the embankment be widened accordingly. The designer must ensure that the embankment widening is included on the design cross-sections. The buried end strengthens the system and prevents spearing. Vaulting may occur if an errant vehicle strikes the end where the mounting height is decreased due to turning down the end. Posts should be installed as shown on the OPS drawings. They must not be flush with the top of the beam.

Other end treatments must be used if the turned down portion is within the clear zone.

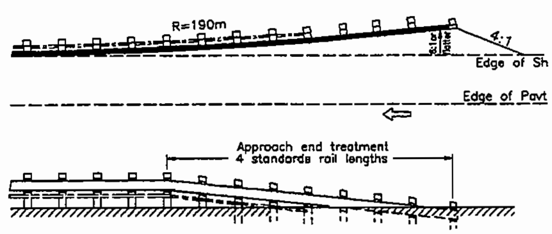


Figure 5.2.3 Flared and Turned Down End Treatment for Steel Beam Guide Rail

For additional information refer to the OPS drawings. This treatment is usually not cost effective on new installations. Existing installations not meeting the above requirements should be removed during reconstruction/resurfacing.

CONCRETE FLARED AND TURNED DOWN END

Ever since this treatment was first used it was recognized that the turned down end of a concrete barrier could cause ramping. However this was considered to be less hazardous than leaving the upright blunt end. With the introduction of new end treatment technology and the increased awareness of safety, the turned down end should be used **only if the turned down portion is completely beyond the clear zone.** For all other applications, the "TREND" treatment is the first choice, with the CAT treatment as an alternative to protect the end on the roadside.

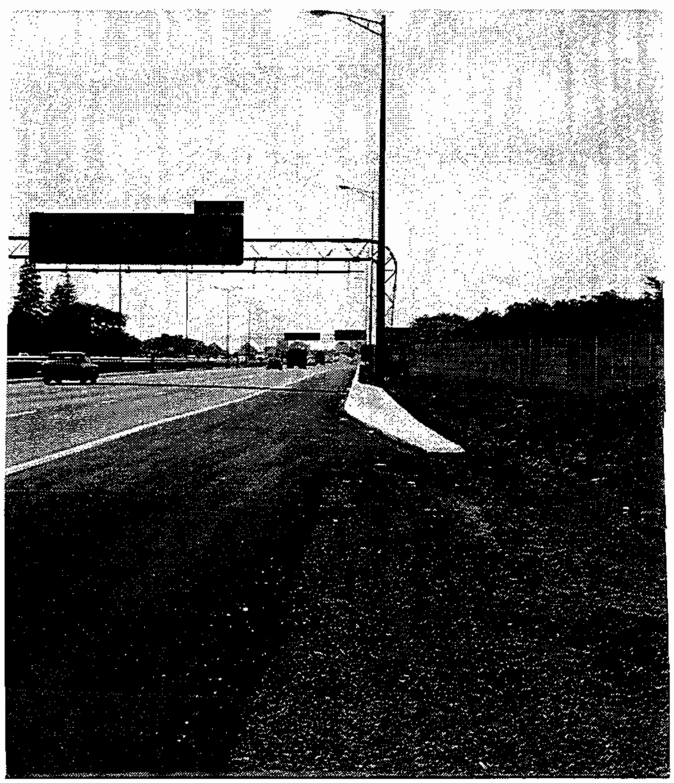


Figure 5.2.4 Concrete Barrier Turned Down and Flared End Treatment

This treatment should no longer be used on new installations. Existing installations should be removed during reconstruction/resurfacing.

5.2.2 GREAT

The Ministry has approved the use of the Guide Rail Energy Absorbing Terminal (GREAT), Figure 5.2.5, as an end treatment. It may be used where traffic travels in both sides of the system. There are two types of GREAT systems, permanent and temporary, both of which are proprietary products developed by Energy Absorption Systems.

DESIGN FEATURES

The GREAT system consists of bays of crushable hex foam cartridges surrounded by a framework of triple corrugated (thrie) steel guide rail panels. The number of bays (to a maximum of 6) are dictated by the design speed of the roadway. The nose section is formed out of a crushable plastic material, but is not counted as a bay. The permanent unit is installed on a concrete slab, while the temporary unit may be installed on a concrete or asphalt pad. Refer to the OPS manuals for additional details.

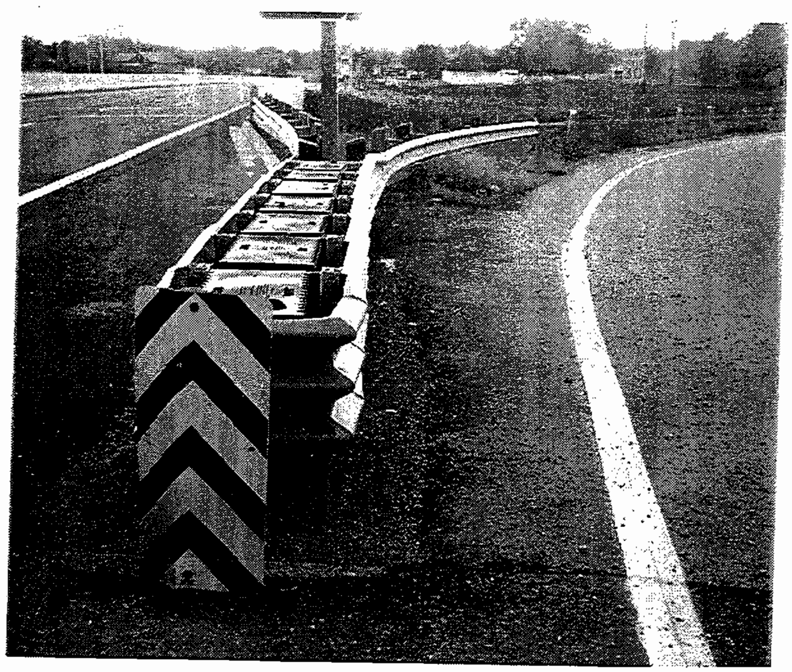


Figure 5.2.5 GREAT Installation

PERFORMANCE (GREAT)

When hit head on the energy absorbing cartridges crush to absorb energy while the steel panels telescope. When struck from the side the panels are restrained laterally by leg pins and guidance cables, and redirect the vehicle with little or no damage to the system. The system can be repaired after all but the most severe hits, ie. it is not considered to be sacrificial.

DESIGN AND INSTALLATION (GREAT)

Each system is individually designed to accommodate site conditions and design speed. The length of the attenuator and of the concrete pad are selected from tables on the appropriate standard drawings in the OPSD manual. Traffic may travel on either side of the system.

Portable units which are used as temporary installations during construction, are available only in 3 or 6 bay configurations as shown on the OPS drawings. They may be converted to permanent installations, provided the design standards for the location are met.

For installations in medians the designer should consult the appropriate standard drawings in the OPSD manual.

Units are available in 3 standard widths, 610, 760, and 915 mm. The designer should select the narrowest width which will adequately protect the hazard. Designs are available to shield objects wider than 915 mm, by using additional thrie beam or transition elements. Designers should contact the Surveys and design Office if assistance is required.

Modification to the system may be required to alleviate problems caused by expansion joints directly below the unit. If expansion joints cannot be avoided, the Surveys and Design Office should be contacted for recommendations or assistance.

To enable optimum performance, it is important that a relatively flat surface be provided to the front and sides of the system. Thus catch basins, electrical junction boxes, and other appurtenances in the area should be relocated, and raised curbs higher than 100 mm must be removed from the front and sides. The system performs best when installed on tangent.

The system can be attached to steel beam, IBC, or concrete barriers. Designers should contact the Surveys and Design office for assistance, if required.

MAINTENANCE (GREAT)

No regular maintenance of the GREAT system is required, but accumulations of ice and snow adjacent to the barrier should be removed promptly.

The system is designed so that after a head on collision a pickup truck can pull the unit back into position. The nose section, foam cells, shear pins, and some fender panels may have to be replaced after a severe impact. Minor head on impacts cause little or no damage, and the system can endure side impacts with little damage.

All damaged foam cartridges must be replaced with products designated by the manufacturer only.

5.2.3 TREND

The Ministry has also approved the use of the TREND system, (see Figure 5.2.6) for use as an end treatment on provincial highways. The TREND is a proprietary product manufactured by Energy Absorption Systems.

DESIGN FEATURES

This end treatment has been designed to provide protection for barrier ends and other fixed object hazards where space is restricted.

The system consists primarily of short overlapped sections of steel thrie beam panels, which are mounted on steel posts installed on slip bases. Some of the posts have energy absorbing containers attached to them. A steel tension strap connects the upper rear of all posts to the hazard being protected. The entire system is anchored to a concrete pad. A cable is connected to the lead post and an anchor block located behind the system. As a result of the cable and anchor block, the TREND cannot be used in narrow medians, gores or areas where there is traffic on both sides.

The total length of the system when attached to a structure is approximately 6 metres, which is the shortest treatment available.

It must be specified whether the system is for right or left side operation.

PERFORMANCE (TREND)

During head on impacts, the vehicle is captured by the nose assembly. The panels telescope and the redirecting cable guides the vehicle behind the barrier and away from the hazard, while remaining engaged with the system. The steel tension strap enables the system to safely redirect an errant vehicle during a side impact collision on the traffic side for either direction of travel.

This system can be readily repaired after all but the most severe impacts. It is not considered to be a sacrificial system.

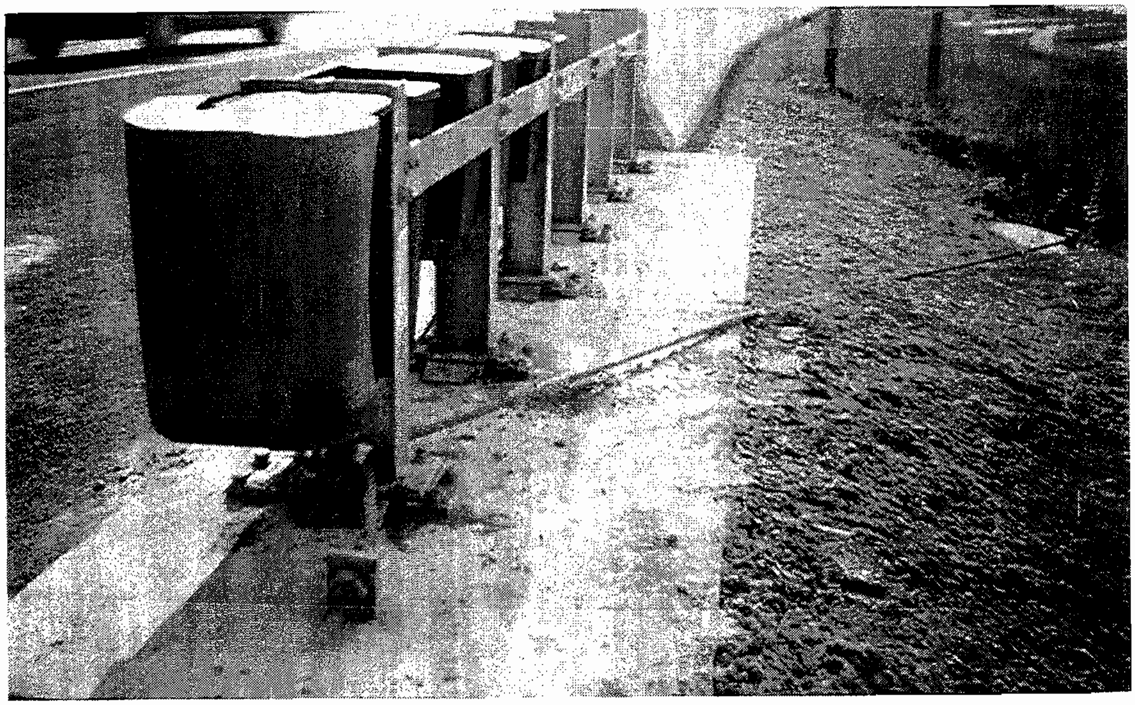


Figure 5.2.6 TREND Installation

DESIGN AND INSTALLATION (TREND)

The TREND is designed to shield rigid barrier ends and other fixed object hazards. Where the minimum length of guide rail required by other systems cannot be accommodated, the TREND must be used. The system is the end treatment of choice for roadside concrete barrier, where traffic travels on one side of the system only.

The TREND cannot be installed in narrow medians because of the cable attached to the anchor block installed beside and to the rear of the system. Care should be taken in interchange areas to ensure adequate clearance between the back of the system and exit ramps, parallel roadways, etc.

The system is designed to be installed parallel to the roadway, and thus does not require widening of the shoulders and fills.

Since errant vehicles are directed behind the system during head on collisions, the area immediately behind the end treatment should be traversable. At least a 6 metre by 6 metre space behind the system must remain hazard free. Where erosion in the vicinity of a structure is a problem, the rip-rap used behind the TREND should not exceed 100 mm. The rear anchor block must not protrude more than 100 mm above the surrounding ground.

Care must be taken to ensure that the system is installed as designed. The panels must be free to telescope, and the slip bases installed in the correct location and orientation.

The TREND system should be placed on relatively flat terrain, with no curb and gutter, and the path between the roadway and the unit should be free of obstacles and irregularities. If curb and gutter is necessary, only the mountable type should be used. If possible, the TREND should be installed on a tangent section of roadway.

MAINTENANCE (TREND)

Except after collisions, little regular maintenance is required. However, snow should be removed from the front and side of the system to ensure its proper performance. Care must be taken to ensure that damaged systems are repaired as designed. Telescopic panels must not be accidentally bolted together, and slipbases must always be installed in the correct location and orientation. The torque on the slip base bolts should be annually checked.

5.2.4 CAT

The Ministry has approved the use of the CAT system, shown in Figure 5.2.7, for use as an end treatment on provincial highways. The CAT system is a proprietary system developed and manufactured by Syro Industries.

DESIGN FEATURES

The Cat system utilizes standard steel beam guide rail panels punched with a continuous set of slots running the full length of the steel beam elements. The steel beam elements are of different thicknesses, with the front set of panels thinner than the second. The steel beams are mounted on wooden posts placed inside steel sleeves that are embedded in the earth. The posts are drilled at the ground level, in the direction of travel, to easier break away when impacted by smaller vehicles. The nose section is constructed of a plain, light weight, crushable steel which is wrapped around the first post. A cable and strut between the first two posts acts to anchor the system and ensure that it can develop full tensile strength for side impacts. A spacer is installed between the two sides to prevent buckling under impact. The total length of the unit, including SBGR transition, is approximately 14 metres when attached to concrete barriers, piers or other such rigid obstacle, and approximately 20 metres when attached to steel beam guide rail. Traffic can travel on either side of the system.

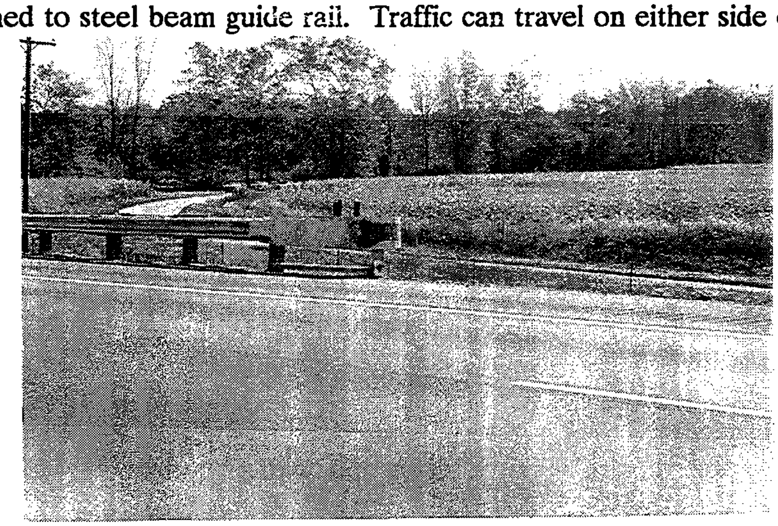


Figure 5.2.7 CAT Installation

PERFORMANCE (CAT)

During a head on impact by an errant vehicle, the nose section prevents spearing and the steel beam elements are forced forward, past shear bolts at specific post locations. As the beam element moves forward, the steel beam material between each slot is shredded by the shear bolts. Energy is dissipated through the shearing action and the breaking of the wooden posts, and the vehicle is decelerated to a safe stop.

The CAT can be struck from either side of the system and in either direction of travel, and will safely re-direct errant vehicles during a side impact hit. The cable and strut between the first two posts are designed to anchor the system during side impacts.

The system will require replacement after all but minor hits, and only the steel post sleeves can normally be salvaged.

DESIGN AND INSTALLATION (CAT)

The CAT system is designed to act as an end treatment for steel beam guide rail and concrete barriers on both roadside and median locations. Hazards which can be protected vary from 0.6 to 2 metres in width. Since the panels are of different thicknesses, care should be taken during the installation process to ensure that the thinner gauge panel is installed at the front of the system. The performance of the system depends on proper installation of the panels.

The system is designed to be installed parallel to the roadway, making it suitable for narrow grade locations, without requiring widening of shoulders and fills. Since it may be struck on either side, it can also be installed at diverging roadways.

The system should be placed on relatively level ground, with no curb and gutter in front of the unit, to ensure optimum performance. If curb and gutter is required, only the mountable type should be specified. The system should be placed on tangent road sections wherever possible.

Care must be taken to install the CAT system as designed, with the lighter gauge panels to the front, and with the proper size and orientation of the post holes to facilitate breaking away.

MAINTENANCE (CAT)

Except after collisions, no maintenance is required. A high speed, head on collision will require replacement of the entire system. Minor head on impacts require the reforming or replacement of the nose section, replacement or straightening of damaged panels, and replacement of broken wooden posts, depending on the severity of the impact. Side impacts, depending on their severity, will require straightening or replacing of damaged panels, and replacing of broken posts.

Broken posts can be readily removed from the metal sleeves and replaced. Staff should ensure that the holes in the replacement posts are drilled as designed to ensure proper performance when hit by small vehicles. As panels come in two gauges, care should be taken to install them in the correct location, since performance depends on correct installation.

5.2.5 ECCENTRIC LOADER

The Ministry has approved the use of the ECCENTRIC LOADER system shown in Figure 5.2.8, for use as an end treatment on provincial highways. The Eccentric Loader is a non-proprietary product.

DESIGN FEATURES

The system consists basically of 2 shop bent steel beam guide rail panels mounted on wooden posts. The panels are not fastened to the posts, but rest on metal angles. The nose consists of a fabricated horizontal steel lever inside a corrugated steel pipe. A metal strut and cable are installed between the first two posts to anchor the system during side impacts. The posts are drilled at the ground level, in the direction of travel, to easier break away when impacted by a smaller vehicle.

The Eccentric Loader is installed on a parabolic curve with a 1.22 metre offset at the nose.

Total length of the system is approximately 7.6 metres.

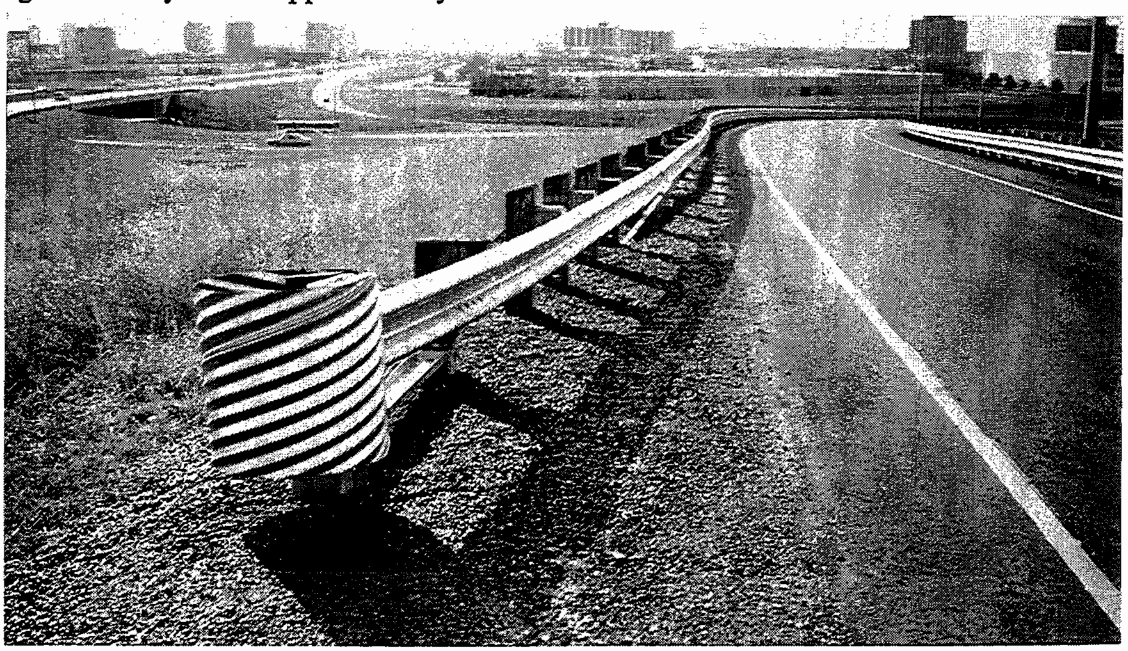


Figure 5.2.8 ECCENTRIC END LOADER Installation

PERFORMANCE (Eccentric Loader)

To perform as designed it is important that the system be installed according to the standards shown in the OPSD manual.

For end on impacts, the end assembly engages the vehicle. The first two posts are designed to fracture, allowing the rail elements to bend away from the vehicle, which then passes behind the terminal. The rail is not fastened to the posts, but rests on metal clips, which allows the rail to buckle. The metal strut and cable between the first two posts are designed to ensure that the system is anchored properly for side hits.

Energy dissipation is achieved through post breaking and through the buckling of the beam elements, which usually fold in two or three locations.

The system will safely redirect errant vehicles after a side impact.

Replacement of the system is required after all but minor hits.

DESIGN AND INSTALLATION (Eccentric Loader)

To ensure the beam can buckle, it is important that the system be installed or repaired to the dimensions shown on the OPS drawings. The beam elements included as part of the eccentric loader must be factory bent. Field bending will make it difficult to install the beams on the metal clips, and may also result in mis-alignment of the system.

The Eccentric Loader is designed as an end treatment for steel beam guide rail or concrete roadside barriers with a transition. It is also recommended for use as the steel beam end treatment in the transition treatment from cable to steel beam guide rails.

The roadside shoulder and associated fills must be widened to accommodate the 1.22 m flare at the nose, when used as an end or transition treatment. The designer should ensure that the widening is reflected on the design cross-sections.

Since the unit is designed to channel vehicles behind the system (gate), away from the travelled lanes, when hit head on, the area behind the end treatment must be traversable and free of fixed hazards.

The terrain behind the guide rail and the Eccentric Loader must be traversable so as to allow a vehicle that penetrates behind the system to come to a safe stop before hitting the shielded hazard.

As with other end treatments, the unit should be installed on a relatively level surface, with no curb and gutter in front of the system, to ensure optimum performance. If curb and gutter is required, only the mountable type should be specified. The system may be used on the left or right side of the roadway by reversing the metal brace. Since the slot on the corrugated steel pipe at the end is not centred from top to bottom, care should be taken to install it as shown on the OPS drawing.

MAINTENANCE (Eccentric Loader)

Except after collisions, no regular maintenance is required.

Side impact collisions will require the replacement or straightening of side panels and the replacement of wooden posts, depending on the severity of impact.

After head on collisions, the corrugated steel pipe section, wooden posts, and bent panels will likely have to be replaced, depending on the severity of impact.
To ensure buckling of the beam, it is important that the system be repaired to a high degree of accuracy to the dimensions shown on the OPS drawings. Under no circumstances should the beam element be bolted to the posts, since they must rest on the metal angles in order to perform as designed.

5.2.6 EXTRUDER

The ministry has approved the use of the EXTRUDER, shown in Figure 5.2.9 as an end treatment on provincial highways. The EXTRUDER is a proprietary product, manufactured by Syro Industries.

DESIGN FEATURES

The system consists basically of two 7.62 m steel beam guide rail elements mounted on wooden, breakaway posts. The posts are inserted in steel tubes set into the ground. The nose consists of a fabricated steel extruder terminal, which is mounted on the end of the steel beam guide rail elements. Additional support for the terminal is provided by two legs which rest on the ground. A metal strut and cable are installed between the first two posts to provide anchorage for the system during side impacts. The posts are drilled at the ground level, in the direction of travel, to easier break away when impacted by a smaller vehicle.

Figure 5.2.9 Extruder

PERFORMANCE

To perform as designed, it is important that the system be installed according to the standards shown in the OPSD manual.

For head on impacts, the extruder assembly engages the vehicle. The steel beam guide rail panels are then forced through the extruder, which bends the panels 180 degrees and at the same time flattens the W shape. The wooden posts are designed to fracture at impact. Energy dissipation is achieved through, bending and flattening of the beam, and the breaking of the posts. The system will safely redirect vehicles after a side impact. After collision the steel beam panels and posts require replacement, however the extruder terminal itself can be reused.

DESIGN AND INSTALLATION

The EXTRUDER is designed as an end treatment for steel beam guide only.

To ensure proper operation of the extruder terminal, the guide rail panels must be 7.62 m long, as opposed to the standard 3.81 m length. They come with the system.

There are no flares or offsets in the systems installation. It must be installed on tangent, parallel to the roadway. Thus the extruder does not require shoulder or embankment widening. The front legs must be planted firmly on the ground, to ensure that the terminal does not twist from self weight. As with other systems the EXTRUDER should be installed on a relatively flat surface, with no curb and gutter in front of the system, to ensure optimum performance. The strut between the part 1 and part 2 may be turned up or down to fit right or left installation.

The terrain behind the guide rail and the Extruder must be traversable so as to allow a vehicle that penetrates behind the system to come to a safe stop before hitting the shielded hazard.

MAINTENANCE

Except after collisions, no regular maintenance is required. The system should be inspected occasionally to ensure that the front legs are resting firmly on the ground. If they are not, the terminal may twist due to self weight, with substandard performance resulting.

After head on collisions, damaged rails and posts will require replacement. The extruder terminal itself will not be damaged and can be re-used. When repairing the system ensure proper posts, drilled to be breakaway, are used, and that the 7.62 m long panels are replaced in kind.

5.3 CRASH CUSHIONS

5.3.1 GREAT

DESIGN FEATURES

The GREAT system described in Section 5.2.2 may also be used as a crash cushion. For this function, a reinforced, free standing concrete backup or steel braced wall must be used as shown on Figure 5.3.1, and in the appropriate OPS drawings. Modification of the system may be required to alleviate problems caused by expansion joints under the unit. If expansion joints cannot be avoided, the Surveys and Design Office should be contacted for recommendations or assistance. Every effort should be made to provide a smooth run-up to the system. If curb and gutter are necessary, only the mountable type should be used.

For additional information on the GREAT system refer to Chapter 5, Section 5.2.2

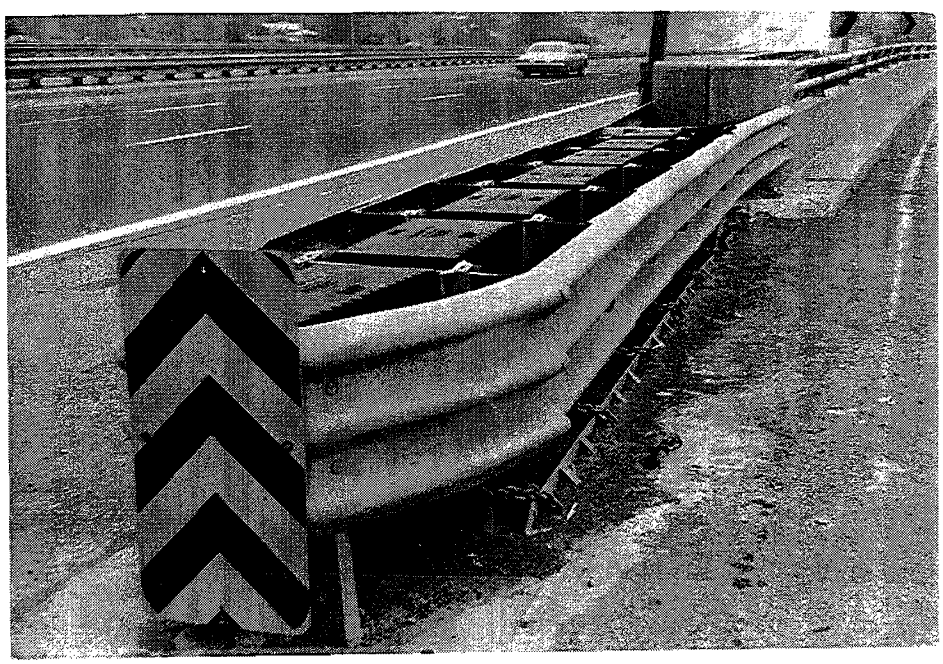


Figure 5.3.1 GREAT System

5.3.2 HI-DRO, HEX FOAM, and HI-DRO CELL CLUSTER

The Ministry has approved the use of the HI-DRO sandwich system, shown in Figure 5.3.2, and the HI-DRO CELL CLUSTER, Figure 5.3.3, for use on provincial highways. The HEX-FOAM SANDWICH SYSTEM, Figure 5.3.4, is an equivalent system that may be used in place of the HI-DRO. The three systems are proprietary products developed be Energy Absorption Systems Inc.

DESIGN FEATURES

The **HI-DRO** system consists primarily of 100 mm diameter, vertical polyvinyl tubes filled with an anti-freeze solution, arranged in bays and separated by diaphragms. There are no diaphragms in the nose section. The sides of the unit are protected by fender panels, and the nose cluster by a safety flex belt. A rigid backup structure is necessary at the rear of the unit. Steel cables extending through the length of the system restrain the unit vertically and horizontally. The entire unit is installed on a concrete pad. The system comes in three standard widths, 914, 1575, and 2286 mm. Special units can be designed by the manufacturer to a width of 4572 mm. The length of the system varies with the design speed of the facility.

The **HEX-FOAM** system is similar to the HI-DRO system and can be used interchangeably. The major difference between the two systems is the attenuating material. **HI-DRO** uses a liquid, while the **HEX-FOAM** uses crushable foam cartridges.

The **HI-DRO CELL CLUSTER** system consists of **HI-DRO** cells bolted together in a cluster, and wrapped with a flexible safety belt. The variety of cluster configurations is virtually limitless, which means the unit can be adapted to fit a variety of applications, such as railroad crossing signals, traffic lights, etc. where protection by other methods is not feasible. The dimensions and characteristics of a given site determine the number of cells required in a unit.

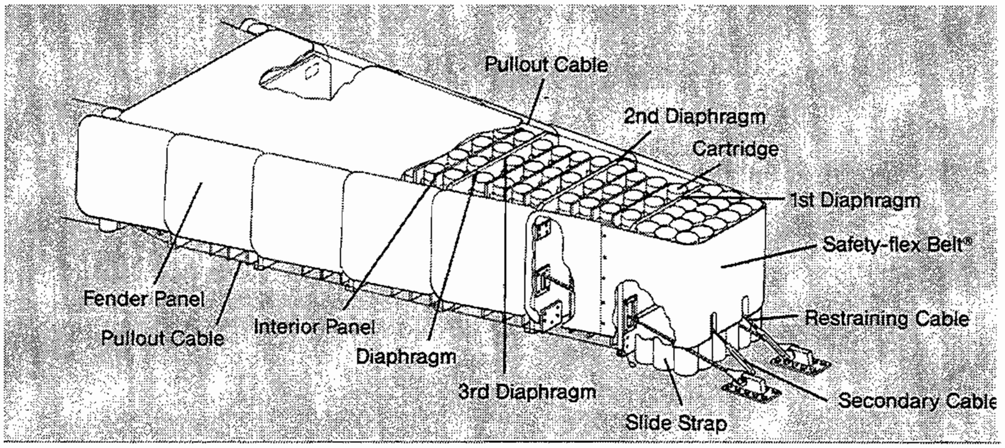


Figure 5.3.2 HI-DRO Installation

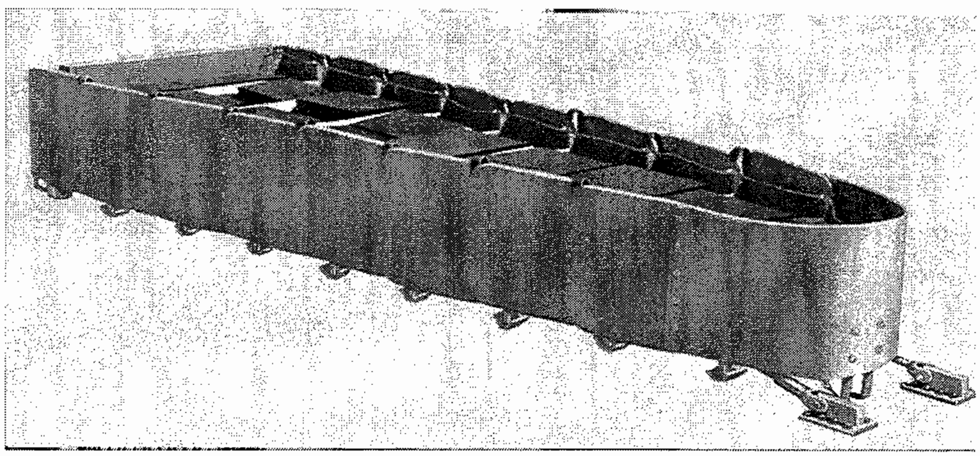


Figure 5.3.3 HEX-FOAM Installation

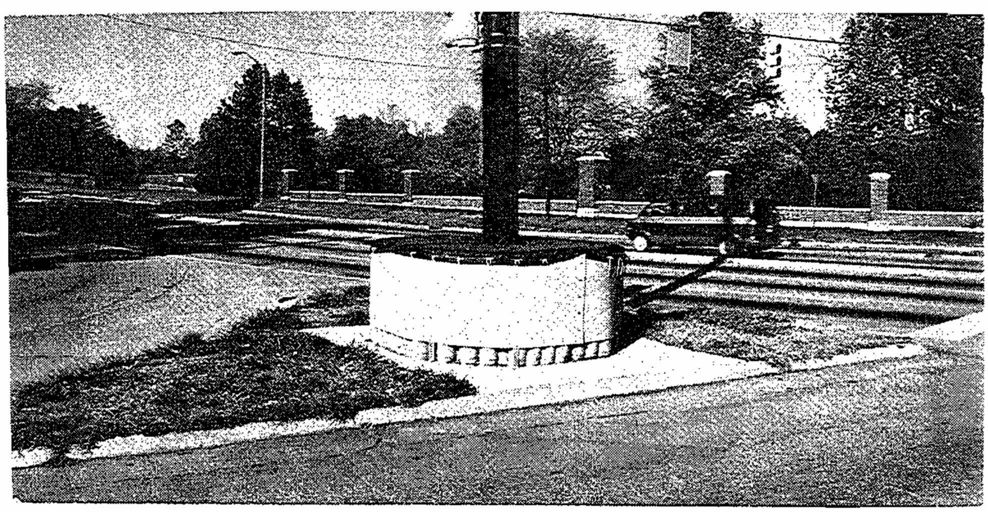


Figure 5.3.4 HI-DRO CELL CLUSTER

PERFORMANCE

HI-DRO

The HI-DRO system absorbs collision energy by forcing the anti-freeze in the vinyl tubes up through orifices in the top of each cartridge unto the roadway, and by moving the mass of the unit rearward as the vehicle slows to a stop. In head on impacts the diaphragms distribute the forces uniformly to all cartridges in each bay until the vehicle stops. The depth of penetration of the vehicle depends on its speed and weight.

The system is designed to safely re-direct a vehicle if hit from the side. The system can be repaired after collisions with minimal effort.

HEX FOAM

The **HEX FOAM** system's performance is similar to that of the **HI-DRO**. With the HEX-FOAM, however, energy attenuation occurs by the crushing of the cartridges, instead of forcing anti-freeze through orifices in the tubes.

HI-DRO CELL CLUSTER

The HI-DRO CELL CLUSTER dissipates energy in exactly the same way as the **HI-DRO** sandwich system, and is effective at speeds of 70 km/hr or less. At locations with higher operating speeds, damage will be sustained and the vehicle may not come to a compete stop before contacting the hazard.

DESIGN AND INSTALLATION

HI-DRO, HEX FOAM, AND HI-DRO CELL CLUSTER

The **HI-DRO** and **HEX FOAM** systems are designed to protect fixed object hazards, such as the barrier ends of structure gores, or barrier ends at diverging roadways. The **HI-DRO CELL CLUSTER** is designed to be used to protect single poles or overhead cantilever signs, such as at railroad crossings, traffic signals that might be hit from any direction, and other locations where space is restricted and an anchored system is impractical.

The designer should select the smallest standard width **HI-DRO or HEX FOAM** which will adequately shield the hazard. The length of the system varies with design speed. Until the OPS drawings and specifications are issued, the designer should contact the Surveys and Design office for assistance in determining the proper design. Each **CELL CLUSTER** is designed specifically for the application, and designers should contact the Surveys and Design Office for assistance.

The designer should be aware that the selection of the **HI-DRO** and the **CELL CLUSTER** energy attenuators may raise concerns in environmentally sensitive areas because of the antifreeze solution in the plastic tubes. If this is the case, the **HEX FOAM** system can be substituted, since it is a similar system using foam cells in place of the liquid filled tubes.

These systems, as well as other energy attenuators and end treatments, should be placed on a relatively flat surface, and the path from the roadway to the system should be clear of obstacles and irregularities, to ensure optimum performance. If curb and gutter is required, only the mountable type should be specified. The above systems must all be installed on a concrete or asphalt pad.

MAINTENANCE

Following most impacts these systems can be restored quickly by re-positioning the units, and refilling the tubes. In the case of the **HEX FOAM** system the cartridges can be replaced. Most side impacts result in little or no damage at all.

Periodic inspections of the system must be made to ensure that the plastic tubes are filled with fluid, and to check the condition of the foam cartridges.

5.3.3 CIAS

The Ministry has approved the use of the CIAS system for use on provincial highways. Currently there is one design for high speed installations. Designs suitable for lower speeds are being prepared. The CIAS in a non-proprietary device.

DESIGN FEATURES

CIAS is an energy attenuator designed to cushion vehicles in a head on collision, and to redirect them in a side impact.

The system is composed of thin walled steel cylinders. The wall thickness of the cylinders is different, depending on the location. Refer to the OPS drawings. The cylinders are bolted together and placed on flat steel rails. The entire system is attached either to a free standing, movable reinforced concrete anchor block, (see Figure 5.3.5) a concrete backwall designed for use with concrete barriers, or a reinforced concrete backwall integral with the concrete pad.

Steel pipes, which are effective in compression, and steel straps which are effective in tension are installed in some of the cylinders (see Figure 5.3.6) to ensure that the system will re-direct an errant vehicle in an oblique or side hit. A vinyl coated nylon cover, or individual lids are installed over the entire unit to prevent snow and ice buildup in winter.

The system can be easily separated into two or three sections for relocation purposes.

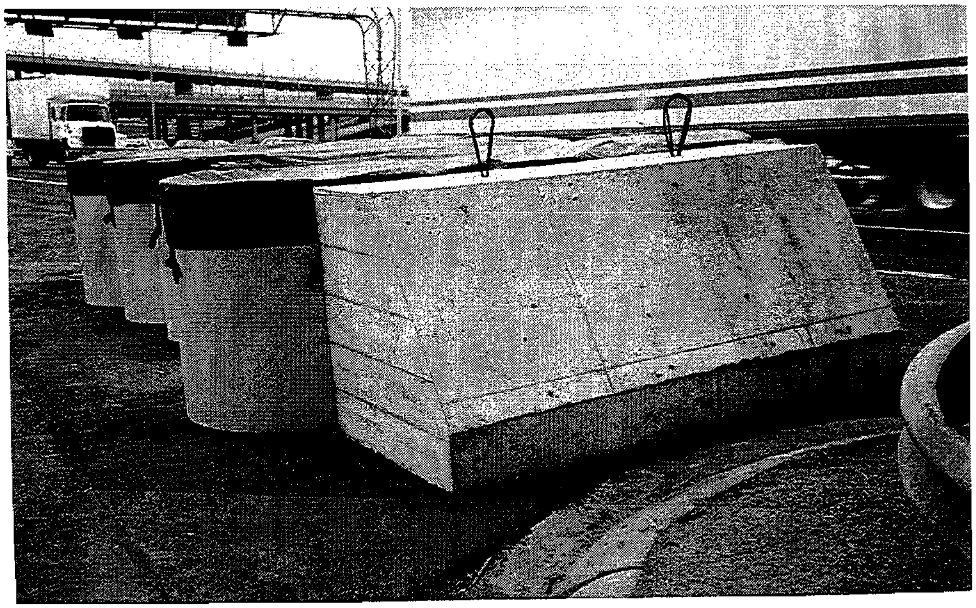


Figure 5.3.5 Concrete Block for CIAS

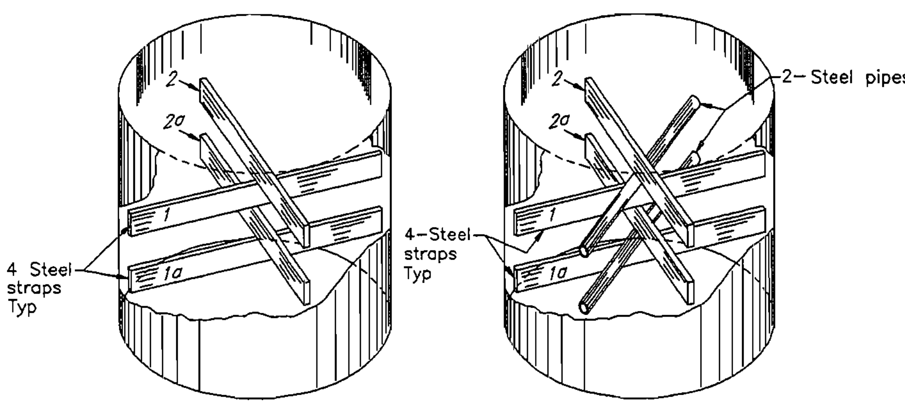


Figure 5.3.6 CIAS

PERFORMANCE (CIAS)

The kinetic energy of an errant vehicle is dissipated by crushing of the steel cylinders. During impact, the crushed cylinders slide on the steel rails and are stopped by the backup structure. The system is designed so that an errant vehicle will be redirected after a side impact. The system will perform adequately even when some of the cylinders are partially distorted by minor hits.

To ensure that the system performs as designed, however, it is important that it is installed correctly. Refer to the appropriate drawings and specifications in the OPSD manuals.

DESIGN AND INSTALLATION (CIAS)

The system is designed for use both in construction zones as a temporary installation, as a permanent installation for the protection of the terminal ends of barriers found in gore areas, and for the protection of median structure piers as an alternative to inertial barrier modules. An advantage of the CIAS system in construction zones is that it can be separated easily into two or three component parts and relocated. It can also accommodate minor hits without needing to be replaced.

If the system is to be used as a permanent installation on a new facility, or at a location without an asphalt or concrete surface, it should be installed on a concrete pad. The pad may slope to best fit the shoulders on each side. At retrofit locations with an existing asphalt surface, there is no need to remove the asphalt and replace it with concrete unless it is in poor condition. If CIAS is used as a temporary system, ie. moved daily or weekly such as in construction zones, a compacted granular surface is suitable under the rails.

It is critical that the cylinders can slide freely on the steel rails. The installation surface must therefore be smooth, and the cylinders must not come in contact with the adjacent surface.

The design layout and cylinder thicknesses must be as shown on the design standards. Variations to the configurations are not acceptable. The CIAS may be installed on a 10 percent slope or less, provided the slope is consistent. To enable the system to perform as designed, the path from the travelled way to the system must be stable, relatively flat, and free of obstacles and irregularities. If curb in front of the system is required, only the mountable type should be used.

Covers must be installed on all permanent installations to prevent ice or snow buildup inside the cylinders, which can prevent free movement on the rails and compression of the cylinders.

Whenever possible the backup structure should be connected to the guide rail systems it shields. It is important that the back up structure is built to dimensions shown to allow for proper anchorage to the system.

Designers should refer to the OPS standards and specifications for additional information.

MAINTENANCE (CIAS)

After impacts the cylinders can be replaced quickly and easily. However, mechanical lifting equipment is required, due to their size and weight. Collisions with the CIAS system will not result in debris scattered on the roadway.

The system's cover must remain intact to prevent snow and ice buildup in the cylinders during winter. This buildup could prevent the cylinders from sliding freely on the steel rails.

The system should be inspected on a regular basis to ensure that the cylinders remain centered on the rails, and that they will slide as designed.

When the anchorage in the back wall is damaged, new positions for the anchors may be found to provide equivalent attachment.

5.3.4 INERTIAL BARRIER MODULES

The Ministry has approved the use of INERTIAL BARRIER MODULES for use on provincial highways. These are proprietary products, the Ministry Designated Source of Material manual should be consulted for approved manufacturers/suppliers.

DESIGN FEATURES

Inertial Barrier Modules are individual free standing containers, 1 m high, and made of a highly frangible plastic material. See the appropriate design standards contained in the OPSD manual. These modules are filled or partially filled with sand to a total mass varying from 200 to 900 kg per module.

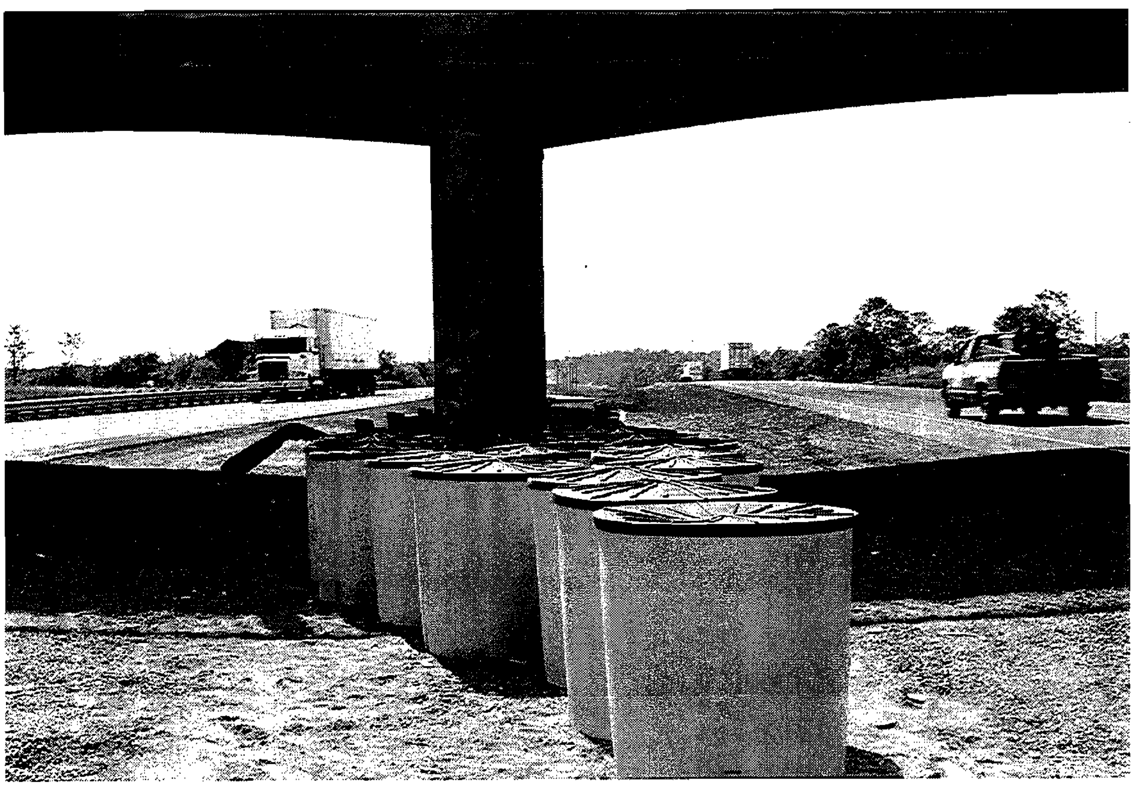


Figure 5.3.8 Inertial Barrier Modules

PERFORMANCE (Inertial Barrier Modules)

Optimum performance depends on the correct design and installation of the system.

The sand filled module systems dissipates the kinetic energy of the vehicle by transferring momentum to the mass of the sand cushion. Varying masses of the sand, located in the upper portion of the modules, control the deceleration of the impacting vehicle. The barrels are normally destroyed even after a minor impact, generating post impact debris. The system performs well for head on impacts, but has no redirection capability for side impacts except at low speeds. No backup structure is required.

DESIGN AND INSTALLATION (Inertial Barrier Modules)

The system must be designed and installed as shown on the design standards in the OPSD manual. Where these standards are not applicable the designer may develop a new design. The system must never be designed as a single row of barrels, except for speeds less than 60 km/hr, and little probability of side impacts. For an overview of design theory and sample calculations, see DESIGN THEORY, later in this chapter.

The system must not be installed where re-direction is a requirement, or where debris scatter can not be tolerated.

The run up surface must be stable, relatively flat and free of large stones or other debris. Barrier curbs, or curbs greater than 76 mm in height, if they cannot be removed or mountable curb substituted, must be situated 4.5 to 6.0 metres from the foremost barrel. Other possible barrier curb locations have guidelines which govern the placement of barrels. For example, if the barrier curb is located within 1 metre of the fixed hazard, the barrels must be placed in front of, or on top of, the curb. If the barrier curb is within 2 metres of the hazard, the rear modules must be placed on top of the raised section. Beyond the 2 metre mark, there are two possible solutions. The barrier curbs can be removed completely, or ramped gradually out into the gore area at a 10 percent slope.

Mountable curbs have little or no effect on the performance of the system, regardless of their location relative to the hazard and barrels. However, design without curb and gutter, even the mountable type, is preferred.

The system may be placed on sloped surfaces up to 10 %. Refer to the appropriate OPS drawings and specifications for guidance.

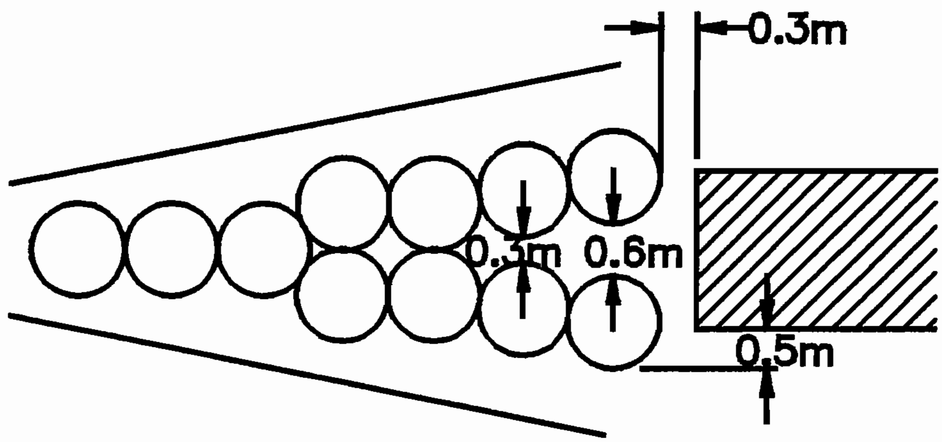
Rear modules should overlap (ie. be wider than) the obstruction by a minimum of 0.5 m on each side. If space allows, a 0.3 m space should be left between the fixed object and the rear line of modules. When the proximity of traffic lanes prevents the use of a wider barrier, the front of the barrier may retain the standard width, but the rear can be widened by spacing as shown in Figure 5.3.9. The spacing dimensions shown, however, must not be exceeded.

Since the average width of a vehicle is 2 m, two modules sitting side by side contribute to the actual deceleration of the impacting vehicle, as shown in Figure 5.3.10. Consequently, the combined weight of both modules must be used in the calculation process. Lead modules should be designed in a single line, to keep the initial G forces to a minimum.

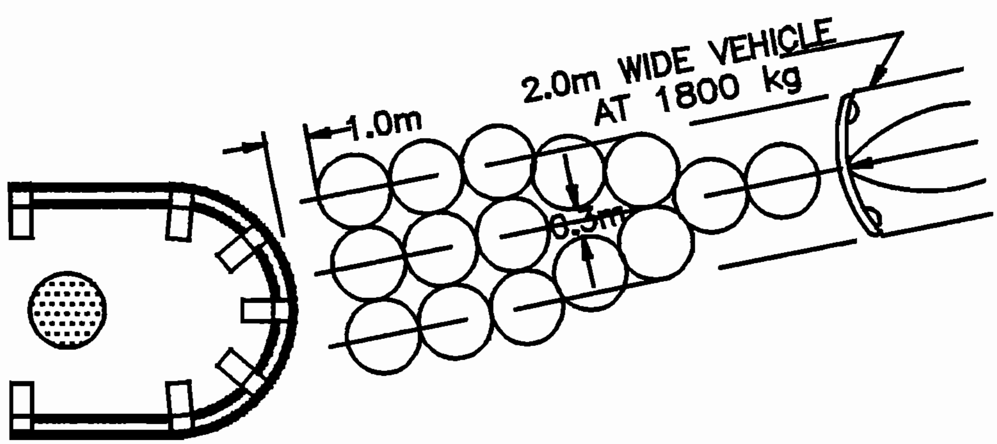
If the hazard is located in the median the Inertia Barrier cluster axis shall be angled 10 degrees toward the oncoming traffic. In gore areas the proper location of the barrier system is dictated by the geometrics of the gore.

In certain instances there may be a lateral grade in the gore area between the throughway and the exit ramp. This is particularly true with exit ramps from elevated or depressed highways. Modules can be placed on crossfalls of up to 10 % without interfering with the effectiveness of the system.

There will be hazards in locations where compromises will have to be made in order to utilize the Inertial Barrier. Where there is insufficient lateral clearance a shallower angle of impact (<10 degrees) may have to be considered. Where there is minimum longitudinal clearance, a higher average G force may have to be designed (Note the reduction in longitudinal distances at higher G's - Graph C). At these restricted locations other devices should be evaluated.



5.3.9 Spacing to increase hazard protection width



5.3.10 Contribution of 2 modules

MAINTENANCE (Inertial Barrier Modules)

The frangible plastic barrels are totally destroyed upon impact, even in minor hits. Typically, 60 % or more of the entire system is destroyed after a moderate to high speed hit. The sand and plastic parts are generally spread over a large area, requiring extensive cleanup. Therefore the system should be used at low risk locations only. When most of the system is destroyed, serious consideration should be given to replacing all the units with a CIAS, using a life-cycle analysis.

It is important that destroyed barrels be replaced and filled with the designed amount of sand to ensure correct operation of the system. Lids must remain on the barrels to prevent moisture from entering the sand and freezing during the winter months.

General maintenance will include a visual inspection at least once a week, and a more formal review of the installation 2 to 3 times a year, at which time the barrels should be checked for correct alignment and general condition.

It is important that the system be restored with the correct size and configuration. The maintenance staff should record the above parameters to facilitate proper retrofit. Modules produced by different manufacturers are interchangeable, provided the size and material mass within the modules are identical.

DESIGN THEORY

A moving body, such as a motor vehicle travelling on a highway, possesses kinetic energy that is determined by:

$$KE = WV^2/2g$$

where KE = kinetic energy (Joules)
W = mass of the car (kg)
V = speed of the car (m/sec)

When stopping a car under normal conditions this energy is dissipated by air drag, rolling friction and braking. These forces, and, in particular, the friction forces between tires and pavement are so low that it takes a substantial distance to bring a vehicle to a full stop.

The principle behind Inertia Barriers is that there is a momentum transfer from the moving vehicle to the barrier element, (the sand) which disperses on impact. Consequently, it is imperative that the barrier systems be installed, maintained and/or replaced in accordance with the initial design, to ensure proper energy transfer and protection against the hazard.

The basic design criteria used by the Ministry are as follows:

Vehicle mass range:	900 - 2000 kg
Design vehicle mass:	1800 kg
Vehicle impact speed:	Design speed to maximum of 110 km/h
Impact angle:	10 degrees as measured from the direction of the roadway.
Desirable (average) vehicle deceleration:	6 g while preventing actual impacting or penetration of the roadside hazard.

Permissible (average)
vehicle deceleration: 12 g maximum while preventing actual impacting or penetration of the roadside hazard.

These design criteria are intended to result in barrier installations for which high-speed vehicle collision would be survivable for the majority of impacts. For barriers which just meet the 12 g requirement of the criteria, injuries of some sort can be expected to unrestrained occupants of a vehicle.

To calculate the approximate length (D) required to decelerate a vehicle to a stop, the following formula or Graph C may be used.

$$D = V^2/(2gGa)$$

where V is initial vehicle speed
g is acceleration due to gravity
Ga is desirable vehicle deceleration

Graph C shows a theoretical vehicle speed/deceleration distance relationship. For example, to bring a vehicle from 110 km/h to a stop at an average deceleration of 6 g, one requires 7.9 m. It is this longitudinal space that has to be filled with the appropriate Inertia Barrier Modules (i.e. a configuration of module weights that ensures an average deceleration). To calculate the distribution of Inertia Barrier mass, the following equations or graphs A and B are essential:

$$v = \frac{V}{1 + \frac{w}{W}}$$ or Graph B

Where v is the final velocity (km/h),
V is the initial velocity (km/h),
w is the weight of the module (kg),
W is the weight of the vehicle (kg).

$$Ga = \frac{V^2 - v^2}{2\,gd}$$ or Graph A

By substituting d = 0.914 m, the diameter of one module, one can determine the average G force (Ga) per module, and the equation becomes:

$$Ga = \frac{V^2 - v^2}{232}$$

Where Ga is deceleration expressed in multiples of g,
V is the initial velocity (m/sec),
v is the final velocity (m/sec),
g is 9.81 m/sec^2,
d is the distance travelled (m).

SAMPLE CALCULATIONS

EXAMPLE 1

Design a single row of Inertia Barrier Modules. (This is for illustration purposes only. A single row of barrels should not be designed or placed in the field)

V = 110 km/h
w = 1800 kg

From Graph C deceleration distance at an average of 6 g's and for initial speed 110 km/h = 7.9 m

For the number of modules required divide 7.9 by .914 (note the diameter of each module is .914 m)
Approximate number of modules = 7.9/0.9 = 8.7 say 9

For the 1st Module

From graph A, and starting with the lightest module (200kg)
initial average g = 9.2

From graph B find the leaving speed (v) for V = 110 km/h and a 200 kg module.
v = 99.8 km/h
This v at 99.8 km/h now becomes the new impact speed V for the next module. The process is now repeated for the next choice of module weight.

For the 2nd Module	Using V = 99.8 km/h
From Graph A	using 200 kg module we get 7.5 g
From Graph B	leaving speed v = 90.6 km/h

For the 3rd Module	Using V = 90.6 km/h
From Graph A	using a 300 kg module results in Ga = 9.8
	using a 200 kg module results in Ga = 6.1

As it is desirable to keep the G forces as uniform as possible in order to reduce the peak G's, the better choice here, would be, the 300 kg module.

From Graph B	leaving speed v = 77 km/h

For the 4th Module	Using V = 77 km/h
From Graph A	using a 300 kg module, Ga = 7.1
From Graph B	leaving speed v = 65.5 km/h

For the 5th Module	Using V = 65.5 km/h
From Graph A	using a 600 kg module, Ga= 8.2

From Graph B leaving speed v = 48.9 km/h

For the 6th Module Using V = 48.9 km/h
From Graph A using a 600 kg module, Ga = 4.6
using a 900 kg module, Ga = 3.2,
Select 600 kg module
From Graph B leaving speed v = 36 km/h

For the 7th Module, Using V = 36 km/h
From Graph A using a 900 kg module, Ga = 3.3
From Graph B leaving speed v = 24 km/h

For the 8th Module Using V = 24 km/h
From Graph A using a 900 kg module, Ga = 1.4
From Graph B leaving speed v = 15.9 km/h

From speeds lower than 17 km/h the vehicle will go through a plowing phase and a 900 kg module will stop a vehicle within 1 m. Thus, calculations beyond this point are not necessary.

For the 9th module to be used should be 900 kg

We thus end up with a configuration such as shown in Figure 5.3.11

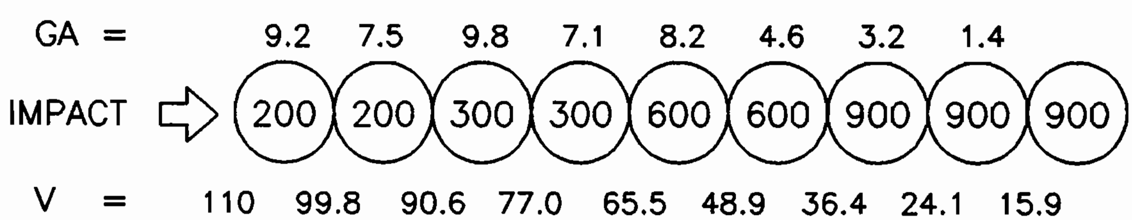


Figure 5.3.11 Example 1, Single Row of Barrels

The foregoing example dealt, for simplicity's sake with only one line of barrels, even though they should never be installed in this manner.

Example 2

Design a double row of Inertia Barrier Modules.
V = 110 km/h
W = 1800 kg

From Graph C deceleration distance at an average of 6 g for 110 km/h = 7.9 m
Approximate no of modules required 7.9/0.9 = 8.7 or 9

For the 1st Module,
from Graph A starting with 200kg module initial g = 9.2
from Graph B leaving speed = 99.8 km/h

For the 2nd Module	using new impact speed of 99.8 km/h
from graph A	using 200 kg module we get 7.6 g. using 300 kg module we get 11.6 g. Select 200 kg module
From Graph B	leaving speed v = 90.6 km/h
For the 3rd Module	Using new impact speed of 90.6
from Graph A	using 300 kg module we get 9.7 g. using 200 kg module we get 6.2 g. Select 300 kg module
From Graph B	leaving speed v = 77 km/h
For the 4th Module	Using new impact speed 77.0 Km/h
From Graph A	using 300kg module we get 7.1 g. using 200kg module we get 4.6 g. Select 300 kg module
From graph B leaving	speed v = 65.6 km/h
For the 5th Module	Using new impact speed of 65.5 km/h
From Graph A	using two x 300 kg modules we get 8.1 g. using 300 kg module we get 4.8 g. Select two 300 modules
From Graph B	leaving speed v = 49 km/h
For the 6th Module	Using new impact speed of 49 km/h
From Graph A	using two x 600 kg modules we get 6.6 g using two x 300 kg we get 3.2 g. Select two x 600 kg modules
From Graph B	leaving speed v = 29.5 km/h

For the 7th Module	Using new impact speed of 29 km/h
from Graph A	using two x 900kg modules we get 2.7 g
	using two x 600kg modules we get 1.5 g
	Select two x 900 kg modules
From graph B	leaving speed v = 14.8 km/h

Since the speed is less than 17 km/h, the vehicle will go into a plowing phase and two x 900 kg modules will be used.

The resulting configuration is shown below in Figure 5.3.12. (An extra 900 kg module is added due to the configuration of obstacle.) Although the final number of modules is less than estimated, the average vehicle deceleration of 6.6 g is still within the acceptable range.

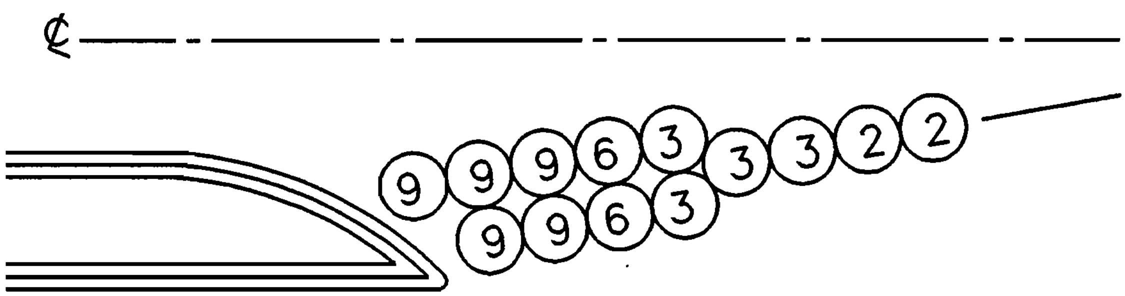


Figure 5.3.12 Example 2, Barrel Configuration

EXAMPLE 3

Design system to protect an obstacle 3 m wide
V = 100 km/h
W = 1800 kg

NOTE: Due to width of the obstacle, the system will be three modules wide, however, a car will only strike the combined weight of the two modules at any one time. Therefore a design maximum of two modules is used.

Form Graph C deceleration distance at an average of 6 g for 100 km/h = 6.5 m.
number of modules = 6.5/0.9 = 7.2 say 7

For the 1st Module	using speed of 110 km/h
From Graph A	using 200kg module we get 7.6 g
From Graph B	leaving speed v = 90.7 km/h
For the 2nd Module	using new impact speed of 90.7 km/h
From Graph A	using 200 kg module we get 6.2 g
	using 300 kg module we get 9.8 g
	Select 300 kg module
From Graph B	leaving speed v = 77.1 km/h
For the 3rd Module	using new impact speed of 77.1 km/h
From Graph A	using 300 kg module we get 7.1 g
	using two x 300 kg module we get 11.6 g
	Select the 300 kg modules
From Graph B	leaving Speed v = 64.6 km/h
For the 4th Module	using new impact speed of 65.6 km/h
From Graph A	using two x 300 kg modules we get 8.2 g
	using two x 600 kg modules we get 10.4 g
	Select two x 300 kg modules
From Graph B	leaving speed v = 48.9 km/h
For the 5th module	using new impact speed of 48.9 km/h
From Graph A	using 600 kg modules we get 6.6 g
	using two x 900 kg modules we get 7.8 g
	Select two x 600 kg modules
From graph B	leaving speed v =29.1 km/h

For the 6th Module	using new impact speed of 29.1 km/h
From Graph A	using two x 600 kg modules we get 2.3 g.
	using two x 900 kg modules we get 2.8 g.
	Select two x 900 kg modules
From Graph B	leaving speed v = 14.2 km/h

Since the speed of vehicle is less than 17 km/h, select two x 900 kg modules for plowing phase of vehicle. The resulting configuration is shown below. (Figure 5.3.13)

It should be noted that for similar design speed and hazard, calculations will not necessarily result in any one unique configuration of barrel weights.

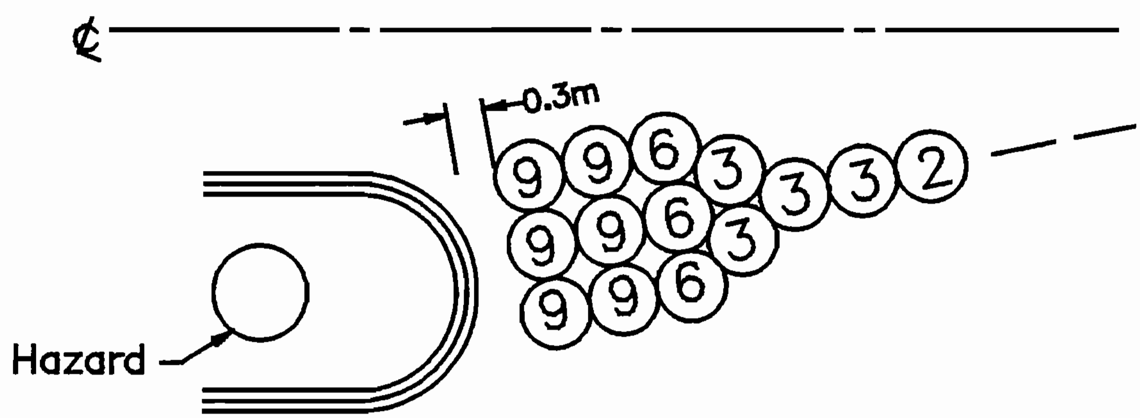


Figure 5.3.13 Example 3, Barrel Configuration

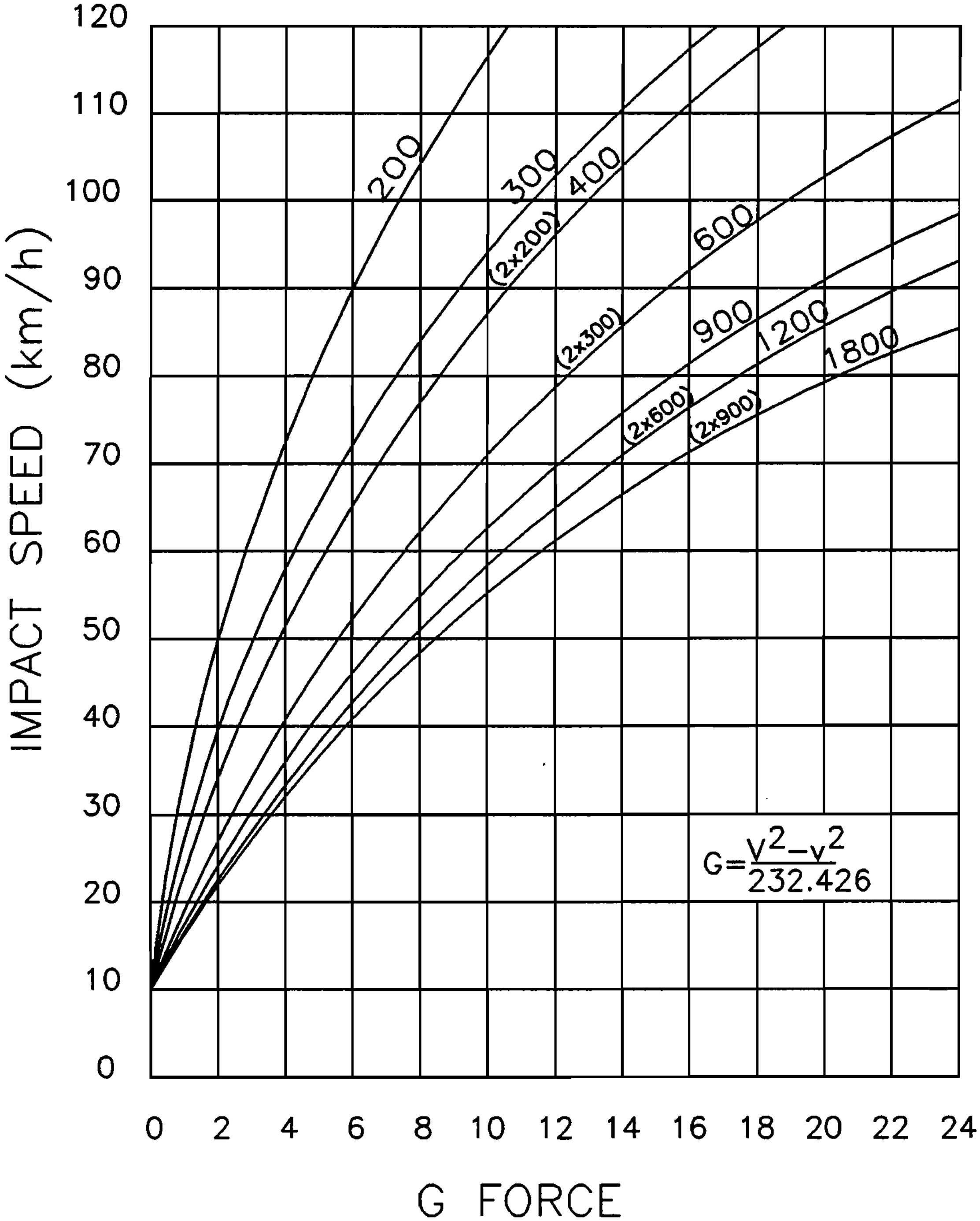


Figure 5.3.14 Graph A

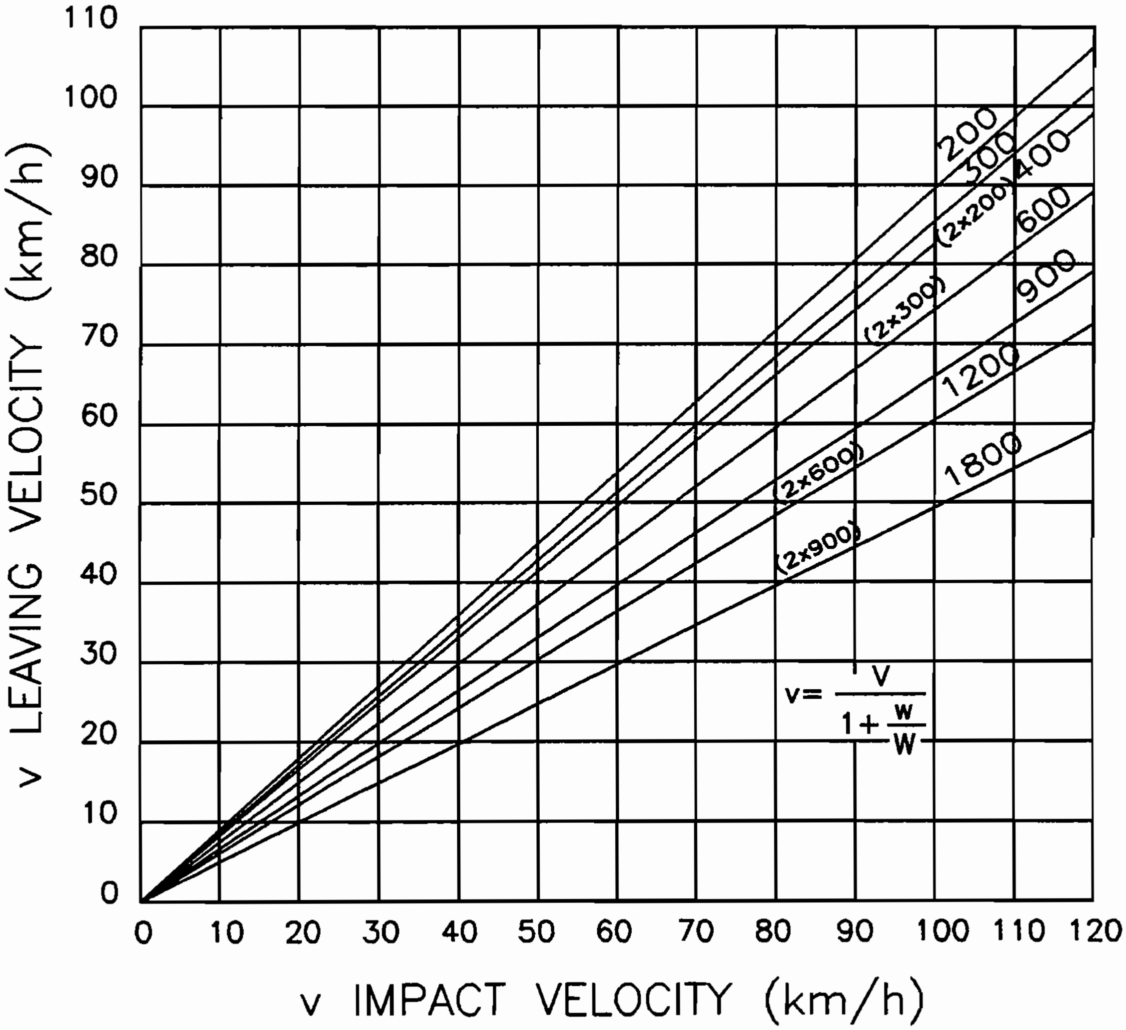


Figure 5.3.15 Graph B

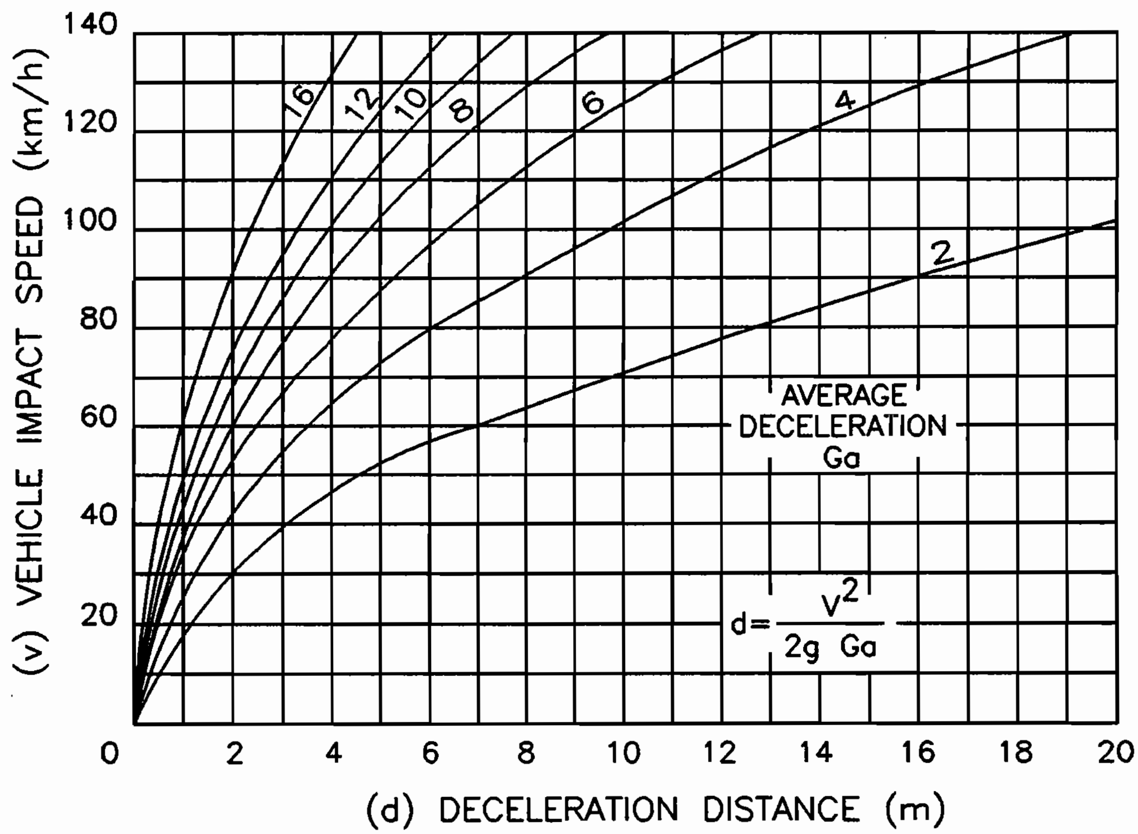


Figure 5.3.16 Graph C

5.4 ARRESTORS

An arrestor is a device or site at least one lane in width that gradually decelerates a vehicle to a stop. Two arrestors which may be used are the Dragnet and the Truck Arrestor Bed.

5.4.1 DRAGNET

The dragnet is a proprietary product distributed by Roadway Safety Services INC. It is designated by MTO as an experimental system and should only be used after discussion with the Surveys and Design Office.

DESIGN FEATURES

The Dragnet consists of anchor posts or some other method of anchorage, energy absorbing reels of steel tape, and a net assembly. Figure 5.4.1 shows a typical installation.

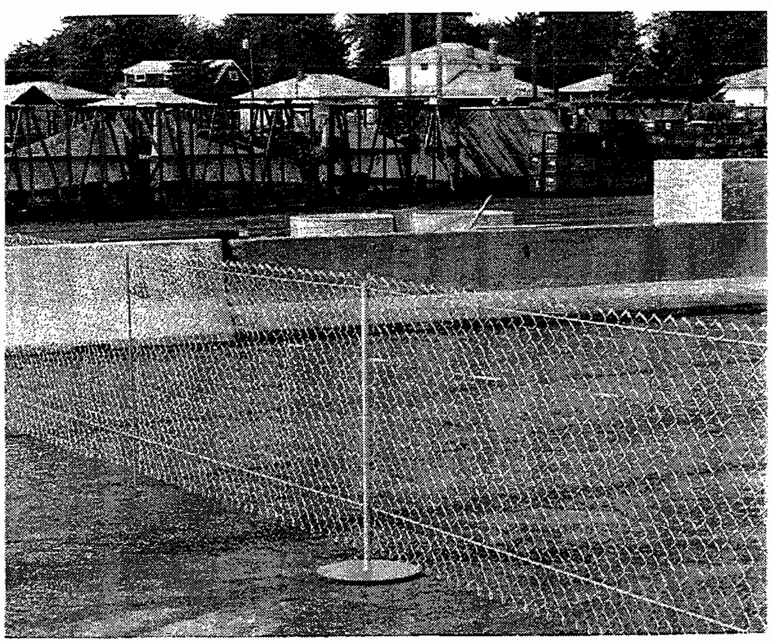


Figure 5.4.1 Dragnet Assembly

PERFORMANCE

The system is designed and has been tested to stop a full sized car travelling at 100 km/h. When hit the netting wraps around the front of the impacting vehicle and the energy of the car is absorbed as the metal tape is pulled through a series of rollers in its casing. The stopping distance for a 2700 kg car is approximately 25 m. Since the Dragnet produces low average decelerations, very little damage is done to the impacting vehicle, and injury to the vehicle occupants is unlikely. A single dragnet is not suitable to stop heavy vehicles, such as trucks or buses.

DESIGN AND INSTALLATION

The Dragnet attenuator may be considered at locations where impacts are expected to be head on, and the results of the vehicle penetration are expected to be severe. Typical locations may be at the approach of a "T" intersection, for temporary road or ramp closures, in conjunction with longitudinal barrier to shield the openings at twin structures with insufficient length to provide the full encroachment length for the longitudinal barrier, or at locations where guide rail can not be installed to protect hazardous locations completely, such as at river crossings with entrances immediately adjacent to the site. Multiple Dragnets may be used in lieu of a truck arrestor bed. (See the next section.)

Since the dragnet deflects considerably, up to 25 m, it should only be used at locations where a clear area exists behind it.

MAINTENANCE

The system is repaired by replacing the steel tape in the casings, and resetting the netting. Repair operation requires little effort by maintenance staff. Extreme care must be taken, however, to ensure that the steel tape is replaced in the correct manner since incorrect placement will render the system totally useless.

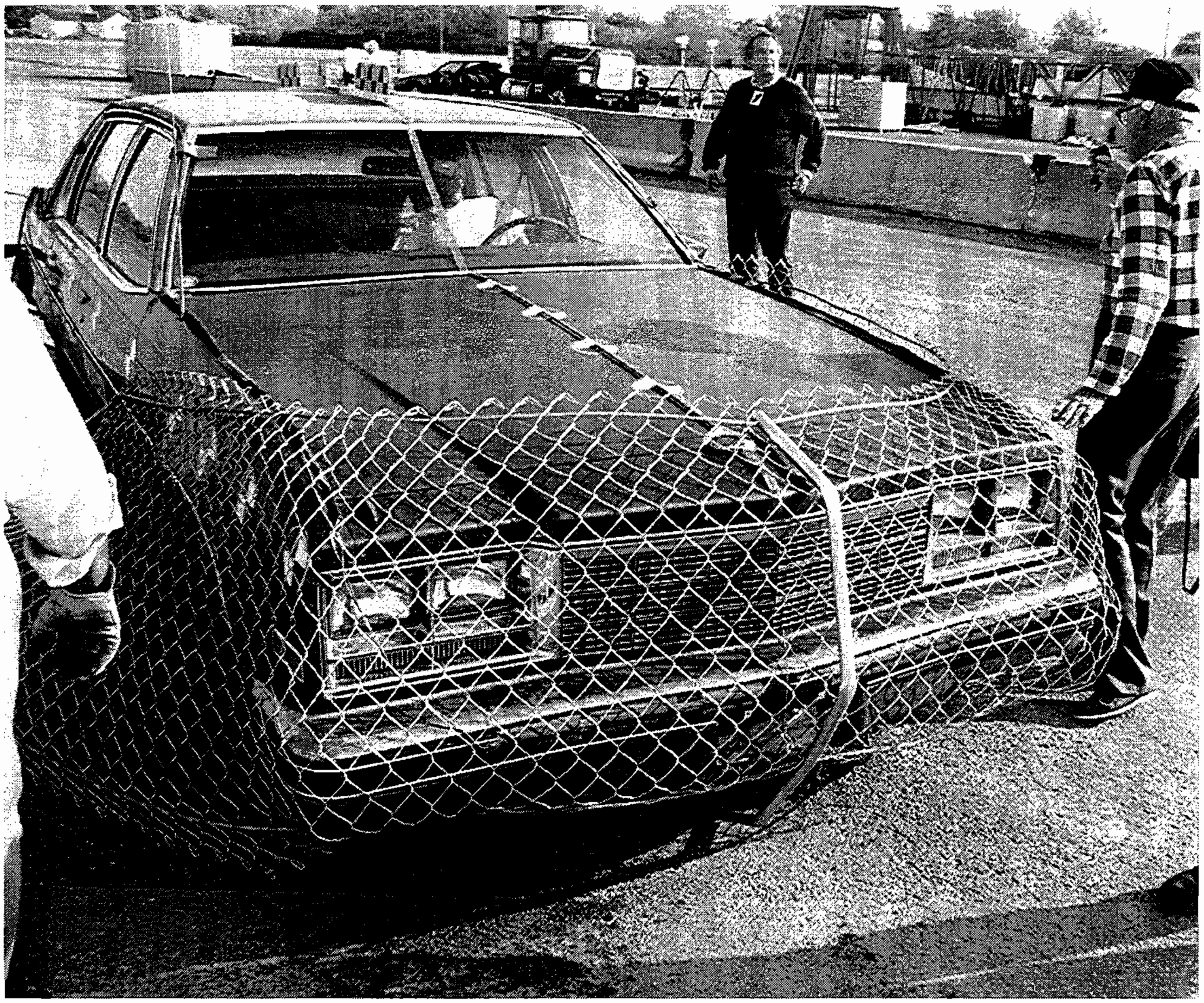


Figure 5.4.2 Vehicle Captured by Dragnet Assembly

5.4.2 TRUCK ARRESTOR BEDS

OVERVIEW

The previously identified crash cushions and attenuators in this section and in section 5.3 are designed for use with passenger cars, and are not applicable for large vehicles. One device suitable for large trucks or buses is a " gravel bed" attenuator. This may be used on truck escape ramps along steep highway grades where runaway vehicles have been or could be a problem.

The Ministry does not have warrants for arrestor beds. Each potential site should be evaluated from a safety and benefit/cost viewpoint. Designers should consult the Surveys and Design and Traffic Management and Engineering Offices for specific suggestions and advice.

While design guidelines for truck arrestor beds are given below, ministry designers should contact the Surveys and Design Office for assistance before proceeding.

Figure 5.4.3 Arrestor Bed in Action

DESIGN GUIDELINES FOR TRUCK ARRESTOR BEDS

General

The AASHTO "A Policy on Geometric Design of Highways and Streets", 1984, states: "Where long, descending grades exist or where topographic and location controls require such grades on new alignment, the design and construction of an emergency escape ramp at an appropriate location is desirable for the purposes of slowing and stopping an out-of-control vehicle away from the main traffic stream".

There have generally been two types of escape ramps constructed in North America. Originally straight gravity ramps were constructed into the side cuts of long mountainous grades. Typically these were simply accessible surfaced side roads on ascending grades, which relied on gravitational forces to decelerate runaway vehicles. Unfortunately experience indicated that these often result in trucks rolling back down and jackknifing on these ramps, causing considerable truck damage and some driver injury. The main disadvantage of gravity ramps is that there exist physical limitations on their location. Very often there is no accessible slope rising from the right side of a highway at a desirable point on the downgrade which could accommodate such a ramp.

To deal with the above-mentioned disadvantages of straight gravity ramps a second class of ramp evolved; the truck arrestor bed. An arrestor is a bed of uniformly-graded, smooth, rounded aggregate. When a runaway truck enters the bed, the truck's kinetic energy is dissipated through the transfer of momentum to the bed aggregate and the overcoming of the aggregate's shear resistance. The truck is thus slowed down, and as the aggregate is being shifted, the truck sinks into the bed, usually to the point where the undercarriage of the truck drags on the top surface. There are many arrestor beds in use in the United States, and several in Canada. They do not cause significant damage to trucks and have performed very well.

The major advantage of arrestor beds is that they may be constructed at highway grade if desired. This largely reduces the problem of locating the bed relative to the problem downgrade. If no other option exists, a designer may configure a roadside arrestor bed (bed along the right edge of pavement) on the downgrade, provided that the calculation of the necessary length takes this negative grade into account. Generally it is more economical to design the arrestor facility making use of any positive grades or level terrain to the right of the downhill lanes of the highway (if their location is appropriate) and to shorten the length of the bed accordingly. Such ascending arrestors, when located off of the downgrade, generally minimize any effects that a bed might have on the through traffic operating on the downgrade. Because of the above-mentioned advantages of arrestor beds, the arrestor bed type of truck escape ramp is preferred for implementation at highway problem sites.

As outlined above, the arrestor bed may be constructed on any grade, if it is designed appropriately. In view of the above and in the interest of clarity, the term 'arrestor bed' is employed in this chapter wherever necessary, and use of the term 'truck escape ramp' is limited to discussions facilities without the aggregate bed.

This section will provide the designer of a truck arrestor bed with enough background information to produce a realistic preliminary design and associated cost estimate for a particular problem location, and to assist in the detailed design of such a facility.

LOCATION

There is no single defined location for the placement of an arrestor bed relative to a problem downgrade. The location is largely governed by the surrounding terrain. It is usually recommended that a bed be considered on the lower half of the grade, since that is where a driver is more likely to perceive a problem. But there have been some beds constructed higher up on long sustained downgrades with curvilinear alignments. These are generally located immediately before defined accident-prone spots such as sharp curves.

The designer must evaluate the site conditions to determine the optimum spot(s) on the downgrade for the implementation of a bed(s).

It is preferable to locate the exit to an arrestor bed on a horizontally tangent section of the downgrade. The placement of the exit area on a curve could add to the control problems for the driver of the runaway. As well, a tangent ramp leaving a curve can, under some conditions, appear as the through roadway to drivers.

There is some debate regarding left versus right hand exits on a divided highway and on multi lane facilities. Arguments supporting the former are based on the idea that speeding runaway trucks operate in the fast lane and therefore would not have to manoeuvre around other vehicles to enter a ramp to the left in the median area. Conversely, proponents of the right hand exit maintain that left hand exits violate driver expectancy.

There are serious reservations about the effects on thruway traffic operation of any left hand exit arrestor scheme, whether on an undivided or a divided highway. It is thus strongly recommended that only arrestor beds to the right of the downhill lanes be considered, unless physical or environmental factors render this solution difficult.

BED APPROACH

An arrestor bed must have an auxiliary approach lane leading off the regular downgrade lanes and into the bed.

This lane should be designed with very 'gentle' geometrics, because, it will likely be used by loaded articulated trucks travelling at very high speeds. Just as the bed itself is usually designed for an entry speed of 146 km/h (see following section), so should the approach lane be designed for very high speeds. The Ministry's Geometric Design Standards for Ontario Highways contains tables of Design Elements for horizontal curves for design speeds up to 130 km/h. It is recommended that the 130 km/h values be used in designing the approach lane.

The approach lane itself should be paved, preferably to the same standard as the regular downgrade through lanes. It should also be of the same width as the through lanes.

It is very important that the approach lane enter the arrestor bed squarely, so that the front wheels of a truck both enter the bed simultaneously. A skewed entry by a runway truck may result in loss of control with a possibility of jackknifing in case of an articulated truck.

BED LENGTH

The length of an arrestor bed is to be calculated in accordance with the method outlined in the AASHTO publication "A Policy on Geometric Design of Highways and Streets", 1984. Therein is contained the following formula:

$$L = \frac{V^2}{30\,(R \pm G)}$$

where L = distance to stop (i.e., the length of the arrestor bed), ft;
V = entering velocity, mph;
G = percent grade divided by 100; and
R = rolling resistance expressed as equivalent gradient divided by 100.

Table 5.4.1 Values of R for Roadway Surfacing Materials.

Bed Material	R
Portland cement concrete	0.010
Asphalt concrete	0.012
Gravel, compacted	0.015
Earth, sandy, loose	0.037
Crushed aggregate, loose	0.050
Gravel, loose	0.100
Sand	0.150
Pea Gravel	0.250

The entry velocity that should normally be used in the calculation of the bed length is 90 mph, unless the roadway alignment is such that it can be assuredly quantified that this entry velocity is overly conservative, and that a lesser speed should be used. Research has verified that the above formula is appropriate for all sizes of trucks.

The recommended bed material for all arrestor beds to be constructed in climatic conditions where snow and substantial freeze-thaw cycles can be expected, is pea gravel. As such the value to be used for R in the length calculation is 0.250, as indicated in Table 4.1.

As outlined above, the AASHTO formula is expressed in imperial units. The 90 mph value of the entry velocity is approximately equivalent to 146 km/h. Once the length of the bed is calculated in feet, the value can be expressed in metric units by multiplying the value of L by 0.3048 to obtain the length in metres.

Most of the arrestor beds in the rest of North America have been constructed wide enough to accommodate two trucks at any one time (8 m wide). This was done because many of these locations have relatively high frequencies of use, especially in mountainous regions, where a second runaway may occur on a downgrade before a previous runaway truck has been extricated from the arrestor bed.

Facilities in locations with much lower runaway frequencies have been designed with effective operating widths of approximately 5 m. This dimension seems to be an appropriate effective design width for arrestor beds in Ontario where low frequencies of use are expected.

Aggregate depths ranging from 0.23 m to 2.4 m have been tested. It was found that the deeper aggregate beds performed better, although once the depth of aggregate exceeded 450 mm, the improvement in performance became marginal.

Typically trucks will sink approximately 300 to 450 mm into the aggregate on an arrestor. A 450 mm depth would appear to be sufficient to offer maximum sinking depth without being so deep that a truck could become unstable and the steering awkward. It should also be noted, however, that over time, fine aggregates collect in the beds and that the fine aggregates become moist and freeze in the winter. The bed's frozen depth would therefore not allow it to function properly.

In view of the above, the design of arrestor beds in snowy climates with freeze-thaw conditions should include a minimum depth of bed aggregate in the range of 450 to 600 mm. Such a range should be sufficient to minimize the effect of fine contamination and not compromise the performance of the bed, resulting in the optimum cost-effective design.

The rate of sinking of a truck into an arrestor bed is not currently known. At the entrance to the bed, the base of the bed should be graded to its maximum depth over a longitudinal length of 15 m, starting with a 0 depth (or close to it). This should allow for safe operation.

In the case of a roadside arrestor bed a tapered exit could also be provided to allow a winch truck to pull a trapped runaway truck out the end of the bed and to allow those runaways that enter the bed late (downhill of the designed entry point) to steer out of the bed after having been decelerated. Such an exit should be graded in approximately the same manner as the entrance described above.

BED SHAPE

The effective operating width of an arrestor bed is the width of the full-depth portion of the bed. The bed itself should be trapezoidal in cross-section with side slopes of 2:1. See Figure 5.4.4. These side slopes serve three functions. First, the relatively gentle slope will permit a runaway truck to enter the bed from the side at a latter point downhill from the actual expected entry point. This would provide a greater margin of safety on the downgrade as a driver may realize that there is a problem after passing the defined exit from the through lanes to the arrestor bed. In such a case, if a roadside arrestor exists, the driver could still steer the vehicle into the side of the bed and make use of the remaining portion of the bed to decelerate.

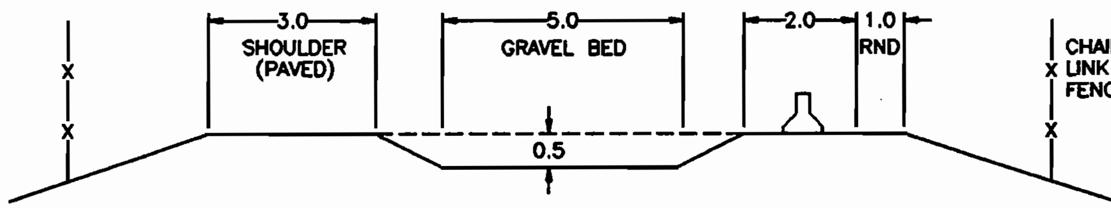


Figure 5.4.4 Cross Section of Arrestor Bed

The second benefit to having these relatively gentle side-slopes is that they will facilitate the extraction of any vehicle which has become embedded in the arrestor.

The final advantage of these relatively gentle slopes is to minimize the loss of control that a driver may experience in an arrestor. Although it has generally been found that a truck is relatively steerable in the aggregate bed, complications could arise if a vehicle is experiencing significant body roll. These 2:1 side slopes should minimize the vehicle instability while helping to keep the vehicle in the bed.

BED GRADATION

Research experience suggests that arrestor bed deceleration values are slightly higher for smaller aggregates, that aggregates must be well rounded to maximize vehicle deceleration, and that smaller aggregates are more likely to become frozen solid due to snow and rain. The level of fine aggregates must be controlled so that they are not present in the operating depth of the bed. They can contribute to the freezing-up of a bed in winter, since water cannot drain quickly enough and become compacted, thus reducing the desirable rolling friction. Larger aggregates are less influenced by freeze interlock, since the contact area is reduced and the volume of voids is much greater, and the trucks can more easily break the bonds between the aggregate. An optimum gradation recommended based on a study of aggregate beds in cold climates, is provided in Figure 5.4.5. Throughout the life of the bed, the aggregate gradation can be affected by the maintenance of the adjacent roadway(s) and the bed, on contamination due to run-off, and on the effectiveness of the bed drainage facilities.

The shape of the aggregate is very important for optimum deceleration. Fractured angular aggregate must be avoided. The percentage of maximum-dimension to minimum-dimension exceeding a ratio of 2 should be no more than 50%. The aggregate must be washed, uncrushed, stream-rounded gravel with a percentage of naturally fractured surfaces not to exceed 10%.

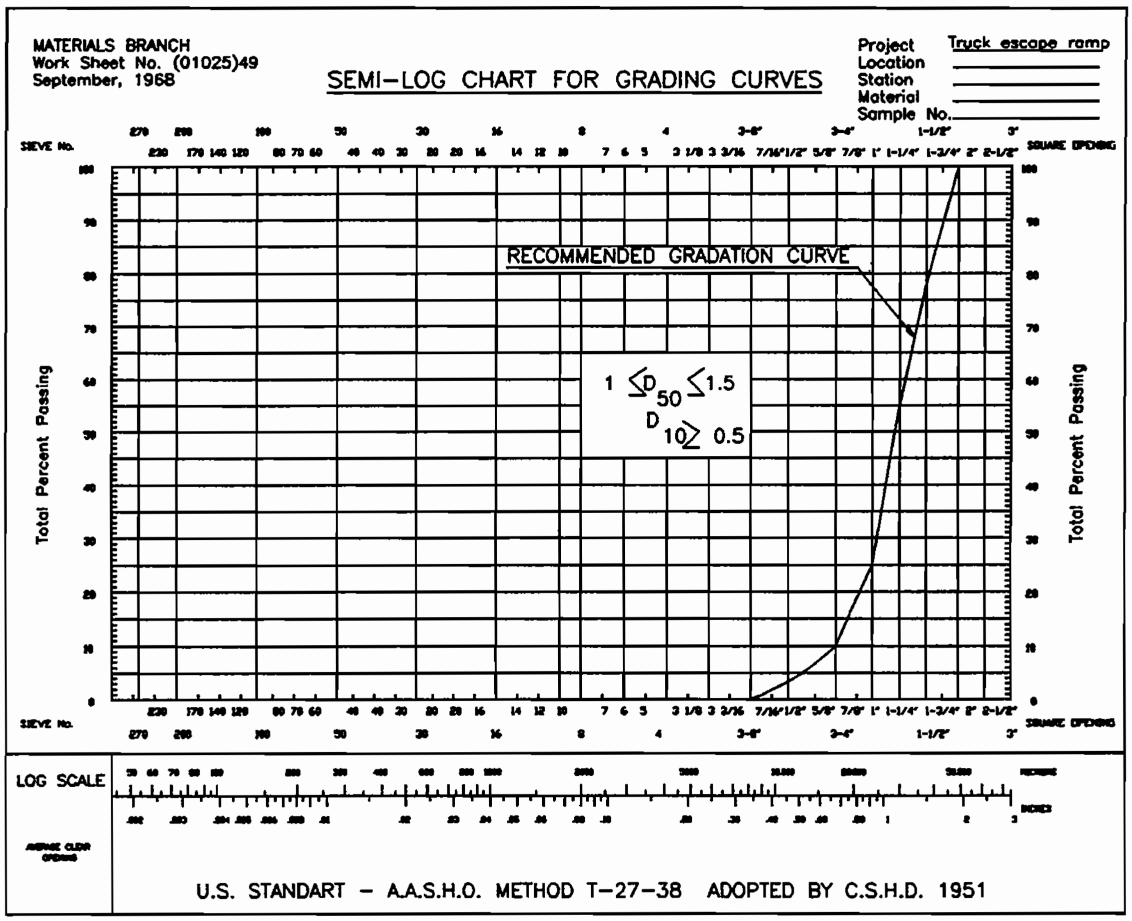


Figure 5.4.5 Optimum Bed Gradation for Cold Climates

BED DRAINAGE AND BASE

Maximum drainage of an arrestor bed is necessary to ensure effective winter operation. Fast effective drainage is necessary mainly to avoid ponding which could freeze in winter and substantially reduce desirable deceleration.

As outlined previously, proper aggregate graduation is the first important aspect. If contamination is present, inadequate drainage will result in compaction and winter freeze-up, and a subsequent reduction in the bed's deceleration capabilities.

An effective collection and drainage system must also be provided. Many arrestor beds are constructed with cross fall grades of approximately 3%, and 150 mm diameter plastic subdrain pipe in trenches with periodic outlets, to ensure effective water drainage.

An open drainage aggregate layer should be provided on the bottom of any arrestor bed. Drainage suggested consists of 150 mm square trenches below the bottom of bed, with coarse backfill and 150 mm subdrains with filter cloth, extending under the arrestor bed out to the roadside slopes, at intervals of about 20 m where a bed is to be constructed. An appropriate positive subdrain system will also need to be devised.

The plowing of snow, which is often laden with fines, onto the surface of the bed should be avoided. Contamination from underneath should also be minimized. Several ways of doing this have been tried by other road authorities, including the provision of a geotextile material between the operating depth of aggregate and an extra drainage layer underneath. However, the most cost-effective solution may be to simply provide asphalt pavement on the base and sides of the bed.

MTO's pavement experts indicate that there should be no problem with the placement of the asphalt on the side slopes. Other road authorities who have used asphalt on the bottom of the bed have experienced deterioration of the asphalt over the years, caused by the leaking of fuels from damaged fuel lines of trucks who had used the bed. In Ontario, however, where high frequencies of use of arrestor, bed are not likely, the deterioration of the pavement would not likely be a serious consideration.

SIGNING, DELINEATION MARKINGS, AND ILLUMINATION

Signing of an arrestor bed should accomplish at least three objectives:

(i) It must inform the operator of a runway vehicle well in advance that an arrestor bed is available, to allow the operator of a runaway truck time to decide whether to use the ramp before reaching the decision point.

(ii) It must make obvious the approach access to the ramp, with adequate sight distance in order to preclude the possibility of the driver missing the ramp.

(iii) Signing at the entrance of the ramp should discourage other highway users from using the arrestor bed, and to avoid impeding access to the bed.

Site-specific signing for any arrestor bed should be devised in consultation with the Ministry's TMEO.

Delineation should be provided to outline the boundaries of the bed and approach for the operator of the runaway truck, and to outline the edge of pavement on the downgrade for all other highway users. The details of delineation for any arrestor bed should be determined in consultation with the TMEO.

It is recommended that pavement markings indicate that the normal travelled way continues on the downgrade. The approach to the arrestor should not be marked in the same manner as normal ramps or exits from the highway, but rather the white (or yellow) solid line at the edge of driving lane should continue right through the exit area. Additional pavement markings should also be placed along the edges of pavement of the approach area to the arrestor bed. These should also consist of the standard solid white lines. Some road authorities have also incorporated the markings "Runaway

Vehicles Only" in the approach area. Pavement marking details for any arrestor beds should be devised in consultation with the TMEO.

ROADSIDE PROTECTION

In trials with one wheel in an arrestor bed and one wheel out, it was found that a truck is pulled sharply into the bed due to the differential drag, and that steering is difficult but manageable. In light of this, one could argue that roadside protection is not needed. In addition, most conventional traffic barriers are adequate to redirect only trucks impacting at relatively low angles. It is felt, however, that the differential drag mentioned above is not sufficiently consistent to be relied upon. It is therefore recommended that where the consequences of a truck exiting out the side of a bed could be hazardous to others (mainly in urban areas), a truck restraining barrier should be provided. The barrier should be the MTO Tall Wall design. In an urban situation this barrier will offer the additional benefits of confining the majority of stone (aggregate) spray when a truck enters the bed, and of limiting access to the bed.

It is also recommended that in urban situations, an arrestor bed be properly fenced and signed to try to minimize the access on the part of children or vandals. An aggregate bed could comprise an enticing play or stone-throw area for children, activities that could be quite hazardous.

SERVICE ROAD AND SERVICE ANCHORS

Except in the case of a roadside arrestor, a surfaced service road adjacent to the entire length of the bed is necessary so that wreckers and maintenance vehicles can be operated without becoming stuck in the bed material. The width of this road is recommended to be at least 3 m.

Tow-truck anchors are necessary for truck removal since it can require a pulling force of up to 3 times the weight of vehicle, according to towing operators, if the truck has sunk 150 mm into a loose gravel. A tow truck alone could not, in such a case, generate sufficient traction or tension.

MAINTENANCE

The bed must be checked periodically to ensure that the bed material is undisturbed. Any vehicle tracks etc., should be levelled. Care must be taken that no fine aggregates are added to the bed material, particularly during snowplowing or other maintenance activities.

DETAILED TABLE OF CONTENTS

6.1 OVERVIEW

Although a traversable and unobstructed roadside is highly desirable from a safety standpoint, some appurtenances simply must be placed near the travelled way. Man-made fixed objects which frequently occupy highway rights-of-way include highway signs, roadway lighting, traffic signals, control boxes, railroad warning devices, mail boxes and utility poles. Approximately 15% of all fixed object fatalities each year involve sign and lighting supports or utility poles.

This chapter is not intended to provide a detailed design guide. Design details for breakaway poles, signs, etc., can be obtained from the Ontario Highway Bridge Design Code and Sign Support Manual. Information on existing operational hardware is included only to the extent necessary to familiarize the designer with the types of breakaway devices available and with how each is intended to function.

The designer's responsibility is to provide the safest facility feasible, within given constraints. As noted in Chapter 1, there are options from which to choose a safe design. In order of preference, these are:

1. Remove the obstacle or redesign it so it can be traversed safely.
2. Relocate the obstacle to a point where it is less likely to be struck.
3. Reduce impact severity by using an appropriate breakaway device.
4. Shield the obstacle with a longitudinal traffic barrier and/or crash cushion if it cannot be eliminated, relocated or redesigned.
5. Delineate the obstacle if the above alternatives are not appropriate.
6. Lower the posted speed. This may not have any effect on the operating speed and should be monitored.

While options one and two are the preferred choices, these solutions are not always possible, especially for highway signing and lighting, which must remain near the roadway to serve their intended functions. This chapter deals primarily with options 3 and 4, the use of breakaway hardware and shielding. Emphasis is placed on the selection of the most appropriate device to use in a given location, and on installing the support to ensure acceptable performance when it is hit.

6.2 HIGH MAST LIGHTING

INTRODUCTION

The Ministry approved the use of high mast lighting system for some applications of full illumination on freeways in 1984, based on the superior lighting quality and cost effectiveness of this method of illuminating the roadway. Further study led to the approval in principle of high mast lighting for partial illumination of both freeways, and other King's Highways. The need or justification for high mast lighting is determined by the Electrical Engineering Section of TMEO.

Due to the massive size and high cost of the high mast lighting fixtures, and the severe consequences if struck, special protection is warranted.

LOCATION

The location of the high mast poles shall be determined on a project specific basis in the following order of priority:

1) Beyond the clear zone as specified in Chapter 2, Section 2.2

2) If there is insufficient room to accommodate the above offsets, the high mast pole will be placed on the outside of the travelled lanes, and protected by a guide rail. Installation must be beyond the deflection distance of the guide rail selected. Cable and Box Beam systems are not suitable barriers to be used.

3) When the above can not be accomplished, or severe problems with light intrusion into the residential neighbourhood are anticipated, the high mast lighting poles may be installed in the centre median.

A minimum 3.0 m shoulder width is desirable next to the widened barrier section of each pole location. For details of the shoulder configuration, consult chapter D-6 Medians of the Geometric Design Standards for Ontario Highways. The special design concrete median barrier shall conform to the Tall Wall design, as outlined in Chapter 4, Section 4.3, and Chapter 2, Section 2.11.

DESIGN AND INSTALLATION

High mast poles must not be located on any bridges. However, they may be located on retaining walls.

High mast poles in all situations must be positioned to provide reasonable access for maintenance, and permit the full lowering of the support ring. In addition, the poles should be located so that maintenance activities can be performed in safety, for both workers and motorists.

The designer shall, in all cases, minimize glare and light encroachment beyond the right-of-way. In areas with any urban or other potential development, the designer shall review the high mast lighting proposal with the Regional Environmental Unit and provide an opportunity for the public to comment, for the purposes of identifying and eliminating of any potential problems.

High mast lighting poles must be positioned so that they meet the Ontario Hydro code for proximity to overhead power lines.

6.3 CONVENTIONAL LIGHTING

GENERAL

The criteria for the selection of pole locations, pole types and types of luminaire mounting brackets have been established under the following objectives:

i) to minimize the possibility of impact by errant vehicles leaving the travelled lanes;
ii) to minimize the severity of injury to occupants and damage to property if impact occur; and
iii) to provide an opportunity to use the most economical pole type and optimum lighting.

When these criteria cannot be satisfied for practical or economical reasons, the use of other alternatives requires the submission of the appropriate details to TMEO, Electrical Engineering Section for approval.

POLICY

WHERE THE DESIGNER IS FACED WITH THE CHOICE OF SATISFYING LIGHTING CRITERIA OR SAFETY (GEOMETRIC) CRITERIA, THE SAFETY CRITERIA SHALL TAKE FIRST ORDER OF PREFERENCE.

ANY POLES WITHIN THE CLEAR ZONE, AS SPECIFIED IN CHAPTER 2, SECTION 2.2, SHALL BE EITHER RELOCATED, MADE BREAKAWAY OR PROTECTED. OFFSETS FOR BREAKAWAY POLES SHALL BE AS DESCRIBED IN THE ELECTRICAL ENGINEERING MANUAL FOR POLE SELECTION CRITERIA.

This policy shall be applied on all highways under Ministry jurisdiction. It is also recommended for application on cost sharing projects, subject to the approval of the local municipality.

The designer shall apply the above policy not only to related groups of poles within a lighting system, but also to specific individual poles within the system where localized conditions warrant.

DESIGN AND INSTALLATION

Where the economics of the different pole types are not a significant factor, the unit which satisfies the structural requirements of the installation, and is the most forgiving on impact, should be considered in the design.

In the design of projects covered within the scope of this policy, wood poles of various mounting heights are considered to have the same hazard potential as non-breakaway poles. Accordingly, they will require the same clearances from the edge of travelled pavement as specified for non-breakaway type poles.

When base mounted poles are selected, care must be taken during design and construction to ensure that the concrete mounting base does not protrude more than .15 m above the ground. Poles must not be placed immediately adjacent to the end treatment of guide rail systems. This is to ensure that the pole will not interfere with the safe operation of the end treatment device.

The designer should give careful consideration to maintenance problem areas in choosing the types and location of poles, to avoid creating maintenance problems such as those arising from poles located in ditch lines, poles located too far from shoulder or a luminaire mounting height that is too high for servicing with available equipment.

BIFURCATION AREAS Refer also to Chapter 2, Section 2.9.

A bifurcation area is defined as the triangular shaped area between two diverging lanes, beyond the point of physical separation of one lane from the other, (see Figure 6.1). This area, is immediately beyond the decision point where a driver must commit to one lane or the other, and lies in the direct line of travel of an over-running vehicle. Consequently, it is potentially much more susceptible to encroachment by errant vehicles than almost probably any other roadside area. It therefore deserves special consideration during design to ensure that it is as free from hazardous obstacles as possible. Thus, the following general requirements should be met;

i) The area between the lanes should be kept clear for a minimum distance of 45 metres beyond the bullnose.

ii) A minimum clearance from the edge of the travelled roadway should be free of any obstacles as shown in Figure 6.3.1, for each design speed.

iii) Whether there is guide rail provided or not, poles shall be located at a minimum distance beyond the bifurcation point in accordance with the following table:

Through Roadway Design Speed	Minimum Distance to Pole From Bifurcation Point
120 km/h	160 m
110 km/h	135 m
100 km/h	105 m
80 km/h	75 m
60 km/h	45 m

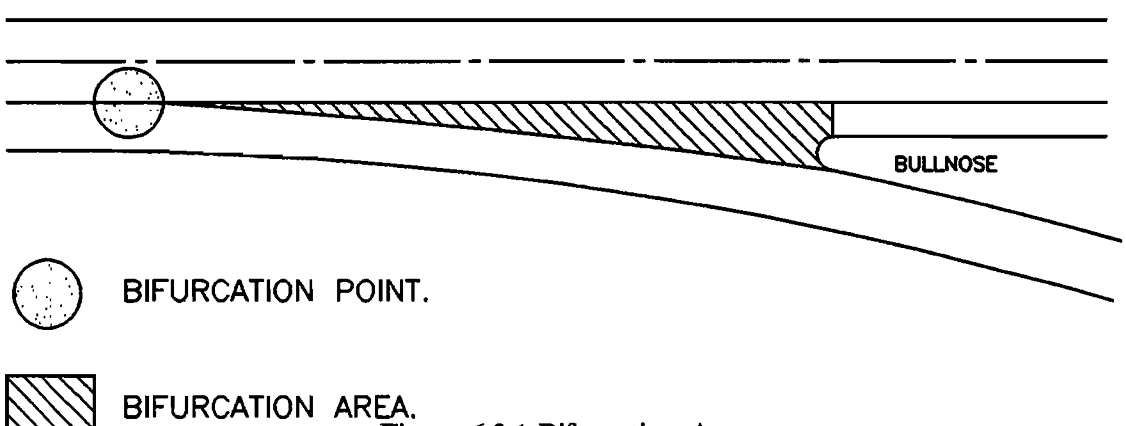


Figure 6.3.1 Bifurcation Area

INTERSECTION AND CHANNELIZATION

Accident experience and statistics have indicated that there are a number of typical interchange areas that are subject to a high rate of encroachment. These are:

i) Spiral over-run areas.
ii) Bifurcation over-run areas
iii) Ramp or loop curve over-run areas.

WOOD POLES

The use of wood poles on Ministry projects will be permitted:

(a) on reconstruction of existing highways where the municipality has adopted the use of wood poles as a local standard;

(b) for temporary lighting projects such as detours;

(c) where the municipality desires to place luminaires on existing utility pole lines; and

(d) where additional poles are required to upgrade the illumination of an existing wood pole system.

6.4 UTILITY POLES

GENERAL

Motor vehicle collisions with utility poles result in approximately 10 percent of all fixed-object fatal crashes annually. This degree of involvement is related to the number of poles in use, their close proximity to the travelled way and their unyielding nature.

As with sign and luminaire supports, the most desirable solution is to locate utility poles where they are least likely to be struck. One alternative unique to power and telephone lines is to bury them, thereby eliminating the potential hazard. Since utility poles are generally privately-owned and installed devices that are permitted on publicly owned right-of-way, they are not under the direct control of the Ministry. This dual responsibility sometimes complicates the implementation of effective countermeasures.

For new construction or major reconstruction, every effort should be made to install or relocate utility poles beyond the clear zone as described in Chapter 2. If corrective action is not practical, a barrier curb may be used for protection for roads with operating speeds 60 km/h or less.

For existing utility pole installations that have been identified as needing corrective action, the decision on the corrective measure to be taken should be based on a site-specific benefit/cost analysis. The following measures could be considered:

- Placing utility lines underground
- Increasing lateral post offset
- Increasing pole spacing
- Multiple pole use (joint usage)

Another countermeasure that can be considered is adequate shielding of selected poles, and particularly the massive supports used for major electrical transmission lines within the clear zone or in other vulnerable locations. Although not a common practice, there may be advantages to delineation of poles that are not otherwise treated, particularly along streets and highways where nighttime run-off-the-road accidents are common.

The designer must ensure that any poles behind a guide rail system are not immediately adjacent to an end treatment device, to ensure proper operation of the system. **The poles must be located beyond the deflection distance of the guide rail but not so far behind as to endanger an errant vehicle that may have penetrated behind the system and is slowing to a stop. They may be shielded by an energy attenuator.**

6.5 BREAKAWAY SUPPORTS

The term "breakaway support" refers to all types of sign, luminaire, and traffic signal supports that are designed to yield when hit by a vehicle. The release mechanism may be slip plane, plastic hinges, fracture elements, or some combination of these. The criteria used to determine if a support is considered breakaway is found in the NCHRP-230.

DESIGN AND LOCATION FOR BREAKAWAY AND NON-BREAKAWAY SUPPORTS

Sign, luminaire and similar posts must first be structurally adequate to support the device mounted on them and to resist ice and wind loads as outlined in the Ontario Highway Bridge Design Code. They must also be properly designed and carefully located to minimize the hazard present to the travelling public. For example, sign supports should never be placed in drainage ditches, where erosion and freezing might affect the proper operation of breakaway supports. It is also possible that a vehicle entering the ditch might be inadvertently guided into the support. Signs and supports that are not needed should be removed. If a sign is needed, then it should be located where is least likely to be hit. Whenever possible, signs should be placed behind an existing roadside barrier, beyond the design deflection distance on existing structures, or in similar non-accessible areas. If this cannot be achieved, then breakaway supports should be used. Only when the use of breakaway supports is not practicable should a traffic barrier or crash cushion be used exclusively to shield sign supports.

As a general rule, breakaway supports should be considered in some urban and most rural areas, or wherever vehicle speeds are moderate to high. A passenger who strikes the interior of a vehicle that hits a nonyielding object at only 40 km/h can sustain substantial injuries. However, in urban areas or other locations, where pedestrians and bicyclists may be struck by falling breakaway hardware after a crash, yielding supports are typically not used. In these cases, barrier style curb and gutter may provide adequate shielding at operating speeds 60 km/h or less. The designer must weigh the relative risks involved in these situations before selecting an appropriate design. Another consideration is the presence or absence of other similar hazards, such as utility poles. It is the isolated hazards that pose the greatest risk, since a motorist may exercise greater care when conditions are perceived to be hazardous.

Supports placed on roadside slopes must not allow impacting vehicles to snag on either the foundation or any substantial remains of the support. The surrounding terrain must be graded to permit vehicles to pass over any non-breakaway portion of the sign installation which remains in the ground or rigidly attached to the foundation. Designers should refer to the Ontario Highway Bridge Design Code and Sign Support Manual in this regard.

Breakaway support mechanisms are designed to function properly when loaded primarily in shear. Most mechanisms are designed to be impacted at bumper height, typically about 500 mm above the ground. If hit at a significantly higher point, the bending moment in the breakaway base may be sufficient to bind the mechanism, resulting in non-activation of the breakaway device. For this reason, it is critical that breakaway supports not be located near ditches or on steep slopes, or at similar locations where a vehicle is likely to be partially airborne at the time of impact.

The type of soil surrounding a luminaire foundation may also affect the performance of the breakaway mechanism. Experience shows that if foundations are allowed to push through the soil, the luminaire support will be placed in bending rather than shear, resulting in nonactivation of the breakaway mechanism. Foundations should be properly sized for surrounding soils.

BREAKAWAY LUMINAIRE SUPPORTS

Breakaway luminaire supports are typically frangible base, slip base, or frangible coupling (couplers) type. Breakaway luminaire supports can be similar to breakaway sign hardware. The breakaway mechanism properly activates if loaded in shear rather than bending, and is designed to release in shear when impacted at a typical bumper height of about 500 mm. Locating supports in the roadside where on impact, they are loaded in bending rather than shear, may result in severe impacts and injuries to vehicle occupants. Superelevation, side slope, rounding and offset, and vehicle departure angle and speed will influence the striking height of a typical bumper. If the negative side slopes are limited to 6:1 or flatter between the roadway and the luminaire support, vehicles should strike the support at an acceptable height provided the roadside is free of all obstacles, including barrier style curb and gutter. If curb and gutter is required, the mountable type is preferred.

As a general rule, a luminaire support will fall near the line of the path of an impacting vehicle. The mast arm usually rotates so it is pointing away from the roadway when resting on the ground. This action generally prevents the pole from going into other traffic lanes and thus becoming another hazard. However, the designer must remain aware that these falling poles may endanger bystanders such as pedestrians and bicyclists, and may be hazardous to other motorists.

When luminaire supports are located near a traffic barrier, breakaway bases may or may not be applicable, depending upon the type and characteristics of the barrier. In general, if the support is within the design deflection distance of the barrier, it should be a breakaway design, or the railing should be strengthened locally to minimize the resulting deflection. Details on traffic barrier types and characteristics can be found in Chapter 4. When luminaires are mounted on top of concrete median barriers, modification to the luminaire support or median barrier, or both may be required. With high-angle impacts into the traffic barrier, or for accidents involving trucks or buses, a luminaire is likely to be struck. With concrete barriers, the chance of this occurring can be reduced by mounting the luminaires so that the face of the pole is a minimum 450 mm from the toe of the barrier. This type of installation generally does not utilize breakaway supports because of the risk a downed pole might present to opposing traffic. Fortunately, such accidents are rare.

A final consideration on roadway lighting is a reduction in the total number of luminaires used along section of highway. The Ministry has adopted the "high mast lighting concept". (Refer to Section 6.2.) Higher mounted lights significantly reduce the total number of supports needed. The ultimate design in this respect is the use of tower or high-mast lighting which requires far fewer supports, located much further from the roadway. This is the preferred method for lighting major interchanges.

6.6 SIGN SUPPORTS

This section is intended to discuss sign supports from a safety perspective. For detailed information on type of support, installation, size, lengths etc., refer to the Sign Support Manual.

OVERHEAD SIGNS

All overhead sign supports located within the clear zone must be shielded with a crash-worthy barrier. If a barrier is used, or is required to shield the object, the sign bridge may be located just beyond the design deflection distance of the barrier, to minimize the required span length. Refer to Chapter 2.0, Section 2.11 for signs mounted on median barriers.

Where possible, overhead signs should be installed on, or relocated to, nearby overpasses or other structures. Overhead signs, including cantilevered signs, generally require massive support systems which cannot be made breakaway, due to load carrying requirements.

ROADSIDE SIGNS

Large roadside signs typically have two or more support posts, generally of wood or steel, which may be made breakaway. The basic concept of the breakaway sign support is to provide a structure that will resist wind and ice loads, yet fail in a safe and predictable manner when struck by a vehicle. Non breakaway supports must be placed either beyond the clear zone offsets, Chapter 2, Section 2.2, or appropriately shielded.

Although the Manual on Uniform Traffic Control Devices (MUTCD) specifies the general location of large roadside signs, the Regional Traffic Sections have a significant degree of latitude in the exact placement of any given sign.

Crash test results show that breakaway supports installed on level terrain will perform as intended when struck head-on by a vehicle. However, if these supports are installed on a slope, or if there is a possibility that a vehicle may be spinning or sliding on impact, the breakaway feature may not function as well as when it is installed on level terrain. Even if a sign is erected on breakaway supports, it can cause significant damage to an impacting vehicle, and resulting injuries to the vehicle occupants.

Once hit, the sign becomes a maintenance problem which is another obvious reason for locating signs where they are least likely to be hit, whether they are breakaway or not.

Smaller roadside signs are supported on one or more posts, generally of wood. Although not perceived as particularly hazardous, small signs can cause significant damage to impacting automobiles. Small sign supports are typically either driven directly into the soil, set in drilled holes, or mounted on a separately installed base. The wooden support posts can be made breakaway by reducing the cross-sectional area, either by using holes or saw cuts. If not made breakaway, the signs should be installed beyond the clear zone offset, or appropriately shielded.

6.7 MISCELLANEOUS DEVICES

Other relatively narrow objects that are usually located adjacent to the roadway include highway traffic signals, railroad warning devices, fire hydrants and mailboxes. These are discussed in the following sections.

TRAFFIC SIGNALS

Traffic signal posts present a special situation where a breakaway support may not be desirable. As with luminaire supports, the immediate hazard created by a fallen signal post must be considered as well as the potential hazard created by the temporary loss of full signalization at an intersection.

When traffic signals are installed on high speed facilities (generally defined as those having speed limits of 80 km/h or greater), the signal supports should be placed as far away from the roadway as practical. Shielding these supports must be considered if they are within the clear zone for that particular roadway, and it is practical to do so. Also refer to Section 2-2-3.

RAILROAD WARNING DEVICES

Warning devices at railroad-highway crossings are generally the responsibility of the railroads. Highway and railroad officials must cooperatively decide on the type of warning device needed at a particular crossing, such as crossbucks, flashing light signals or gates. As a minimum, crossbucks are required and should be made breakaway, much like an acceptable wood post sign support. Other warning device supports, such as signals or gates, are considered to be a hazard, but are not generally break-away. In these cases, consideration should be given to shielding the support with a crash cushion if the support is located in the clear zone. Longitudinal barrier is not considered appropriate, because there is seldom enough space for a proper downstream end treatment. A longer hazard is created by installing a guide rail, and a vehicle striking a longitudinal barrier when a train is occupying the crossing will likely be redirected into the train. The designer must also be aware of the immediate hazard to other motorists just after the devices are knocked down by impacting vehicles.

Because of the advanced warning of the crossing, and driver expectation, the use of a reduced clear zone may be appropriate. However, the designer must still justify the reduced offsets.

In urban areas, where it has been determined that the operating speed is 60 km/h or less, and the clear zone offsets cannot be met, barrier curb may be used to shield the hazard.

FIRE HYDRANTS

Fire hydrants are another type of roadside feature which may be a hazard. While most fire hydrants are made of cast iron and could be expected to fracture upon impact there has not been any crash testing meeting current testing procedures to verify that the designs meet breakaway criteria.

Whenever possible, fire hydrants should be located far enough away from the roadway so they are not a hazard to the motorist, and yet are still readily accessible to emergency personnel. Shielding with a barrier curb and gutter on facilities with operating speeds 60 km/h or less may be considered if other alternatives are not practical.

MAILBOXES

Neighbourhood delivery and collection box units are owned by the postal service, and are a specialized type of multiple mailbox installation that should be located outside the clear zone, particularly on high-speed or heavily travelled highways.

CHAIN LINK FENCE

There are locations in the province where chain link fencing or anti-glare screens are in close proximity to the travelled roadway. Those with a "pipe top rail" represent a potential spearing hazard.

Any chain link fence or anti-glare screen located within the clear zone described in Chapter 2, Section 2.2, must use a galvanized tension wire as the top member, and not a pipe top rail. Any existing installations must be modified if they are within the above offsets from the travelled roadway.

PEDESTRIAN SIDEWALK RAILS

There are numerous designs of pedestrian sidewalk rails that may potentially cause spearing of vehicle occupants striking the railing. The maintenance staff should inspect these and secure the ends so that individual rails may not detach on impact and act as a spear.