DESIGN BULLETIN #75/2012

Alberta Roadside Design Guide
High Tension Cable Barrier System – Median and Roadside Installation

Summary: The subjects covered by this bulletin are as follows:

1.0 SUMMARY

This Bulletin is issued to inform practitioners of the department's guidelines on the use of High Tension Cable Barrier (HTCB) installed in the median and on the roadside (or right hand side in the direction of travel) of the roadway. Cable barrier has been proven to effectively prevent or reduce the severity of median cross over crashes and run-off-road crashes. HTCB installed at median and roadside locations has been shown to be the most forgiving barrier system available for reducing the severity of run-off-road crashes in many applications.

The department has conducted a before-and-after safety evaluation of the 11 km median HTCB on the Deerfoot Trail in Calgary installed in May 2007. To date the barrier system has performed very well. No vehicles have crossed the median into oncoming traffic since the installation. There have been no cross-the-median fatalities. Also, there has been a significant reduction in the frequency (per km per year) and rate (per million vehicle-kilometres) of severe median collisions which are defined as collisions involving major injuries and fatalities.

A preliminary before-and-after safety evaluation of the 122km median HTCB on Highway 2 completed in June 2010 between Airdrie and Red Deer and on the narrow median section near Leduc also indicates substantial reduction in the frequency and rate of severe median collisions.

Depending on the application, HTCB generally has many advantages over other types of barrier systems. Advantages of HTCB include the following:

- Tensioned cables deflect and cushion the force of the hitting vehicle, and are therefore a more forgiving barrier system when compared to concrete and steel systems (i.e. F-Shape, Single Slope Concrete, W-beam, Strong Post, Thrie Beam, Modified Thrie Beam, Box Beam etc).
- Reduced snow drifting
- Low risk for motorists (greater deflection)
- Reduced collision severity (i.e. fatalities and injuries)
- Reduced damage to vehicles
- Cost to install is generally less than concrete and steel barrier systems
- If impacted, relatively fast and easy to repair
- Often continues to provide protection even after impact and prior to repairs. The tension keeps the cable near the design height even when the posts are damaged and or have broken off.
- Improved sight distances in problem areas
- Aesthetic appeal

2.0 LONGITUDINAL TRAFFIC BARRIER SYSTEM SELECTION

As indicated in the Alberta Transportation Roadside Design Guide, November 2007, practitioners should select a median or roadside barrier system based on the following:

Longitudinal traffic barrier systems that are more forgiving are preferred because they may reduce injuries and fatalities when crashes occur, provided that suitable operating space is, or can be made, available.

In order of most forgiving to the most rigid barrier systems typically used in Alberta, HTCB is the most forgiving. Concrete barrier systems are the least forgiving (most rigid).

2.1 Alberta Transportation Product Development and Acceptance Testing

Alberta Transportation's product list of proven, trial and potential products for cable barrier and vendor information is available at the following link indicated below. There are currently four suppliers of proprietary HTCB on the Product List (dated January 24, 2012). http://www.transportation.alberta.ca/689.htm

3.0 OVERVIEW OF HIGH TENSION CABLE BARRIER

Generic (non-tensioned) cable barrier has been used as median and roadside barrier since the 1930s. HTCB has supplanted the generic cable barrier as a median barrier since the 1980s.

HTCB has three or four 19 mm (3/4 inch), 3x7 galvanized steel cables (comprised of 3 x 7 strands of steel) held at the desired height by weak steel posts that are placed in sleeves in concrete or steel foundations. The cables are individually connected to end terminals anchored in steel or concrete foundations. Cables are pre-stretched (in most cases) and post-tensioned after installation to a value depending upon ambient temperature, e.g. 25 kN (5,600 pounds) at 21 C (70 F). The posts are expected to break away on impact, and the tensioned cables deflect and cushion the force of the hitting vehicle. Cables are typically supplied in 1,000 ft. (303 m) lengths, and are connected by turnbuckles or acorns. The cables are very strong and will normally deflect but not break in typical highway crashes.

3.1 Testing and Approval of HTCBs under NCHRP Report 350 and/or MASH 2009

As of March 2011 there are five suppliers of proprietary HTCB systems listed below in alphabetical order.

- Brifen Canada
  15521 Marine Drive
  White Rock, BC V4B 1C9 Canada
  www.brifencanada.com
- Gibraltar
  320 Southland Road
  Burnet, Texas 78611 USA
  www.gibraltartx.com
- Nucor, GSI Highway Products 720 West Wintergreen
  Hutchins, Texas 75141 USA
  www.gsihighways.com
  (Note: Not on Alberta Transportation's Products List dated April 6, 2011)
- Safence
  1557 NW Ballard Way
  Seattle, WA 98107
  http://www.safence.com/indexe.htm

- Trinity Highway Safety Products
  2525 North Stemmons Freeway
  Dallas, Texas 75207 USA
  www.highway-safety.com

All HTCB systems work on the same "physics" principle, but can vary significantly in post cross section, cable/post connection, cable heights, design of post and anchor foundations, post spacing, test deflection, etc. It should be noted that some of the five suppliers supply only four-cable HTCB, while others supply both three-cable and four-cable HTCB.

New HTCB systems and any major changes to existing systems are required to be tested by independent laboratories under prescribed conditions (see below). The test results are submitted by the suppliers to the US Federal Highway Administration (FHWA), which then issues acceptance letters, based on the test results, for individual systems. FHWA letters identify, among other things, the major properties of the HTCB system such as test post spacing and test deflection; and the letters also include or refer to various FHWA and AASHTO guidelines and caveats for the placement and installation of the particular system being accepted.

Until recently all longitudinal barriers accepted for highway application were required to meet the test conditions stated in the Transportation Research Board National Cooperative Highway Research Program NCHRP Report 350, which established six Test Levels (TL) for longitudinal barriers.

TL-1, TL-2, and TL-3 tests involve two test vehicles, an 820 kg car impacting a barrier at 20 degrees and a 2,000 kg pickup truck impacting a barrier at 25 degrees, at speeds of 50 km/h for TL-1, 70 km/h for TL-2, and 100 km/h for TL-3.

TL-4 adds an 8,000-kg single-unit truck at 15 degrees and 80 km/h to the TL-3 matrix; TL-5 substitutes a 36,000-kg tractor/van trailer for the single-unit truck; and TL-6 substitutes a 36,000-kg tractor/tank trailer.

No HTCB has been tested at TL-5 and TL-6 to date.

MASH 2009 (Ref. AASHTO- MASH 2009) The Manual for Assessing Safety Hardware 2009, published by AASHTO, is an update to and supersedes NCHRP Report 350 for the purpose of evaluating new safety hardware devices. MASH was developed through NCHRP Project 22-14(02). MASH contains revised criteria for impact performance evaluation of virtually all highway safety features. Updates to MASH include an increase in the size of several test vehicles to better match the current vehicle fleet, changes to the number and impact conditions of the test matrices, and more objective, quantitative evaluation criteria.

An implementation plan for MASH that was adopted jointly by AASHTO and FHWA states that all highway safety hardware accepted prior to the adoption of MASH – using criteria contained in NCHRP Report 350 – may remain in place and may continue to be manufactured and installed. In addition, highway safety hardware accepted using NCHRP

Report 350 criteria is not required to be retested using MASH criteria. However, new highway safety hardware not previously evaluated must utilize MASH for testing and evaluation.

It should be noted that for installation on 6H:1V or flatter side slopes FHWA has accepted both TL-3 and TL-4 systems of the five suppliers; these acceptances were based on tests on level ground. However, in the tests on 4H:1V slope the suppliers have tested their 6H:1V TL-4 systems only with a pickup truck and not with a single-unit truck; and therefore FHWA has accepted the 4H:1V tests only as TL-3 systems. There are no TL-4 systems available for installation on 4H:1V slopes. It should also be noted that there is no accepted HTCB for installation on side slopes steeper than 4H:1V.

The information above pertains to installations on median slopes or down the slope on “roadside” type installations typically on undivided highways. Barrier design for the median is relatively complex as the designer needs to consider the possibility of impacts on both sides of the system (vehicles possibly coming up the slope or down the slope). In roadside (non-median) applications the slope on the road side of the barrier is of interest (for crash performance) whereas the slope behind the barrier has little influence on crash severity outcomes. Consequently the use of HTCB in roadside applications can be similar to conventional barriers where the barrier is installed on shoulder. The slope prior to impact would be the roadway surface slope and the slope after impact could be relatively steep (up to 2:1 or flatter if required for soil stability) without affecting barrier performance adversely. This is consistent with how the department allows steeper slopes behind barrier systems with conventional barriers such as the Alberta Weak Post W Beam system which is also a "flexible" system. In roadside applications the provision of an offset between the edge of shoulder and the barrier system is desirable and can be achieved by providing a suitable flat slope as per the Drawing RDG-B2.4.

4.0 GENERAL DESIGN PROCESS

This section describes the suggested design process for HTCBs. The specific design guidelines are indicated in the next section. The interactive nature of the various design elements and the physical site characteristics may necessitate an iterative design approach. Designers are encouraged to review the documents (pre-engineering reports, design criteria, special provisions and tender packages) for HTCB projects previously implemented in Alberta. However, these documents are unique to the respective projects, and cannot be directly used on other projects.

4.1 Obtain Information Regarding Available Accepted HTCB Systems

All cable barriers shall meet the crash test requirements of NCHRP Report 350 or MASH 2009 (AASHTO, Manual for Assessing Safety Hardware 2009), as accepted by FHWA in acceptance letters issued for individual HTCB systems and products. The FHWA acceptance letters on cable barrier systems can be found on the FHWA web page for longitudinal barriers.
http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/

Due to ongoing development, new products, research, studies and guidelines on cable barrier, designers shall research and review studies, guidelines, products currently available, tested, and accepted by FHWA at the time of the project.

There may be a time lag between the issuing of FHWA's acceptance letters and posting of the letters on the FHWA website. FHWA also issues periodic guidelines regarding HTCB, such as the July 20, 2007 Memorandum from Jeffrey A. Lindley, Associate Administrator of FHWA, on the subject of "INFORMATION: Cable Barrier Considerations". Designers should therefore contact FHWA to obtain the latest information regarding HTCB-related acceptance letters and guidelines.

Designers shall review the FHWA acceptance letters, and the test documentation upon which the letters are based in detail. This includes the summary results (e.g. test deflection), test site conditions (e.g. post spacing, soil data, etc.), product details, provisions, etc. in which the product was tested and accepted under.

High Tension Cable Barriers are proprietary products and therefore must be installed and maintained in accordance with the manufacturer's and/or vendor's specifications. Cable barrier products vary substantially in details, specification and method of installation, etc. Designers shall review the FHWA acceptance letters in conjunction with the manufacturer and/or vendor's product details and specifications.

When reviewing the FHWA acceptance letters and the suppliers' literature, the following are some of the factors that should be kept in mind.

- More than one FHWA acceptance letter issued on different dates may apply to a given HTCB system, because of updated products, newer components or design changes tested and submitted by the suppliers.
- FHWA might have permitted interpolation, e.g. for correlation between test deflection and post spacing, on the basis of tests done at various post spacings. Also, FHWA might have, without a new test, allowed the addition of a fourth cable to a previously tested and accepted three-cable HTCB system.
- As noted above, for installation on 6H:1V or flatter side slopes FHWA has accepted both TL-3 and TL-4 systems of the five suppliers; these approvals were based on tests on level ground. However, in the tests on 4H:1V slope the suppliers have tested their 6H:1V TL-4 systems only with a pickup truck and not with a single-unit truck; and therefore FHWA has accepted the 4H:1V tests only as TL-3 systems. There are no TL-4 systems currently available for installation on 4H:1V slopes. The

“slope” described here refers to the slope a vehicle would be travelling on prior to impact with the system and therefore this is the slope on both sides of the system in a median application and only on the road side in a roadside application.

It would be useful to compile a summary table that shows the relevant comparative characteristics of the available accepted HTCB systems, e.g. TL-3/TL-4, three-cable/four-cable, post spacing, test deflection, FHWA guidelines/restrictions regarding placement in the median, etc.

4.2 Compile the Physical Characteristics of the Project Site

As indicated below, the lateral placement of the HTCB in the median or roadside is a crucial design decision, which in turn requires a detailed knowledge of the nature and location of the physical characteristics of the project site. This information in the form of plans and summary tables would ideally be based on accurate Record Plans that show both above ground and subsurface conditions, supplemented with specific field measurements during the design stage, particularly at the structures. The designer will also need information about the subsurface soil conditions and the nature of the drainage. This could come from record plans or geotechnical investigation conducted during the start of the design phase. Of particular interest are items such as median width, shoulder width, side slopes, protected as well as unprotected hazards in the median, existing guardrails protecting median hazards, and presence of transverse or longitudinal utilities.

4.3 Determine if there is Sufficient Space for HTCB Deflection and Decide on the Test Level (3 or 4) and Three-Cable or Four-Cable Configuration.

Designers must assess the deflection room available for safe operation of the HTCB system regardless of whether it is a median or roadside application.

HTCB’s are generally not suitable for very narrow medians (normally the median width should exceed twice the width of the deflection). The width of median is measured from the inside edges of travel lanes of opposing directions of traffic. Based on the physical characteristics of the project site and the characteristics of the available accepted HTCBs, the designer will be able to make an initial observation of whether sufficient room is available to accommodate the test deflection of the available accepted HTCB systems plus an allowance for a safety margin (where appropriate).

HTCB should generally not be installed in the median if the above deflection condition is not met. However there may be an exception where the risk is considered low for the intrusion of opposing vehicles into the travel lane caused by the impact to the cable system on the back-side and or where there are significant benefits expected due to reduction of collision numbers or severity.

In terms of TL-3 vs. TL-4, it is desirable that cable barriers for median applications meet the crash test requirements of NCHRP Report 350 TL-4. However, as noted above, TL-3 is the only FHWA-accepted HTCB available for installation on 4H:1V slopes. Refer to Slope Placement below for details of slope constraints.

For roadside applications where the design speed is greater than 100 km/h, the cable barrier must meet the crash test requirements of NCHRP Report 350 Test Level 3 as a minimum.

HTCB systems using either three or four cables are acceptable for median and roadside application (provided that they have been tested and accepted to the appropriate test level under NCHRP 350 or MASH 2009 criteria). It should be noted that three-cable and four-cable systems at a given test level may have equivalent acceptance in FHWA letters for given suppliers.

Recent research by the National Crash Analysis Center (NCAC) in the US has shown that adding a fourth cable to the generic three-cable design increases the likelihood that the cable barrier will catch a broader spectrum of vehicles. It should be noted that there is a variety of spacings in terms of cable heights among the various cable barrier system designs tested under NCHRP 350 criteria. Current research efforts are considering whether these cable height spacings will be adequate to accommodate the larger pick-up truck which is defined in the Manual for Assessing Safety Hardware *(MASH 2009).* HTCB must be installed and maintained to the design height and tension in accordance with the tolerances of the manufacturer's or vendor's specifications to optimize its performance.

Pre-stretched, post tensioned galvanized cables shall be specified for Alberta Transportation projects. Pre-stretched cables have advantages including tension relaxation after installation and reduced dynamic deflection by reducing the play between the individual wire strands in the bundle that forms the cable prior to installation.

4.4 Ensure Competitive Bidding

To allow for a competitive bidding environment, during the design and tendering process designers shall specify the HTCB technical and performance requirements (rather than naming a particular product).

The objective is to ensure that as many as possible among the suppliers with accepted products are able to bid on the HTCB contracts. To do so, designers may need to exercise some discretion, judgment and flexibility. For example:

- Within the constraints posed by the physical characteristics of the project, designers would need to set the specified maximum deflection at a value equal to or higher than the highest test deflection among the eligible accepted systems.
- If the department specifies a four-cable system on 4:1 median side slopes (as was the case for the Highway 2 HTCB project), there was only one supplier with a four-cable system which had been tested on a 4:1 slope. A second supplier had an accepted three-cable system for 4:1 slopes however had not tested its four-cable system for 4:1 slopes but had FHWA acceptance for it on 6:1 slopes. To ensure competition from at least two suppliers, in this case the specifications were written in such a way that allowed the first supplier to bid with its accepted 4:1 four-cable system, and allowed the second supplier to add a fourth cable (per its 6:1 accepted system) to its accepted 4:1 three-cable system. The logic was straightforward: even though the second supplier did not have a test-based FHWA acceptance letter for its four-cable system, adding a fourth cable to its accepted 4:1 three-cable system would only improve its performance.

4.5 Specify the Design Criteria

It is recommended that design criteria unique to the project be created and used in the design. The following is a list of items that are typically included (there may be other items), in a Design Criteria table.

DESIGN CRITERIA TABLE (EXAMPLE ONLY)	
Item	Design Criterion
Installation Type (Roadside or Median)	
Cable Barrier Type (TL-3 or TL-4)	
3-Cable or 4-Cable	
Specified Maximum Deflection	
Desired Space for Deflection	
Minimum Space Between Parallel Barrier Systems	
Transition Between Barrier Systems	
Minimum Space Between Ends of Barrier Systems	
Conditions Where Cable Barrier could replace Existing Barrier Systems	
Maximum Post Spacing	
Product Specification	
Placing in the Median	
Placing in the Roadside	
Placement on Horizontal Curves	
Median Crossovers for Emergency and/or Maintenance Access	
At-Grade Intersections	
Maximum Un-interrupted Length	
Breaks or Interruptions in Cable Length	
Subsurface Investigation	
End Anchor Foundation Design	
Anchor End Terminal	
Possible Requirement for Selective Grading	
Other	

4.6 Undertake the Design

Considering the design criteria unique to the project and the physical characteristics of the project site, the detailed design can now be undertaken, including plans and cross sections. Designers should ensure appropriate documentation of where and why the design criteria may not have been met.

4.7 Package the Tender

The tender package should include requirements to submit FHWA acceptance letters and the tests they were based on, so that the designer can have confidence that the product that is supplied will meet the performance expectations that the design is based on. The submittals should demonstrate that the foundation components of the proprietary cable barrier system have been designed and authenticated to suit the unique soil (and other) conditions of the site.

5.0 DESIGN GUIDELINES

This section deals with the major elements in HTCB design.

5.1 Maximum Specified Deflection and Post Spacing

A review of FHWA acceptance letters indicates that HTCB systems have been tested on flat ground and on 4H:1V slope at various post spacing ranging from 2 m to 10 m, with test deflections ranging up to 3.7 m. In general, the test deflection (i.e. the deflection that the test barrier experiences when hit by the test vehicle at certain speeds and angles) is known to increase with longer spacing between posts. According to FHWA, what is not known, but strongly suspected, is that longer post spacing may also affect the propensity for vehicles to penetrate the cable barrier, i.e. by under-ride, over-ride or traveling between cables.

At a given test level, the test deflection on 4H:1V slope has been found to be larger than the test deflection on flat ground.

The guideline for setting the maximum specified deflection for median HTCB installations is as follows:

- Within the constraints posed by the physical characteristics of the project it is desirable that designers set the specified maximum deflection at a value equal to or higher than the highest test deflection among the eligible accepted systems so as to allow several suppliers to potentially bid on a project.

Two Alberta examples illustrate the application of this guideline. On the Deerfoot Trail median HTCB project, which had a 6H:1V median sideslope throughout the project, the maximum specified deflection was set at 2.4 m, based on FHWA's 6H:1V acceptance letters. This allowed several suppliers to potentially bid on the project.

On the Highway 2 median HTCB project, the median side slope varied from 6H:1V to 4H:1V. On the basis of FHWA's 4H:1V acceptance letters, the maximum specified deflection was set at 2.7 m. This allowed at least two suppliers to potentially bid on the project: one had a test deflection of 2.6 m, and the other had a test deflection of 2.7 m. A third supplier's test deflection of 3.7 m was ruled out of consideration as being too high.

In terms of post spacing, since the HTCB systems must be installed as tested, the post spacing associated with the test deflections are of course fixed. Therefore designers do not have a choice to specify the post spacing at which a given HTCB system is installed. However, designers can specify a maximum value for post spacing.

Alberta's HTCB projects to date have specified a maximum post spacing of 6.1 m. However, in the interest of promoting competition, designers should exercise some discretion in the terms of maximum post spacing. For example, a recent 4H:1V accepted HTCB has post spacing of 6.4 m and with a test deflection less than some competitors at

6.1 m post spacing. In this case it may be logical to specify a maximum post spacing of 6.4 m.

5.2 Placement of HTCB in the Median

There are several requirements or guidelines that need to be met when deciding where in the median the HTCB is to be placed. The main ones are discussed below.

5.3 Desirable Deflection Space

Cable barriers can normally be hit from both sides when installed in the median of divided highways (unless there is another system that prevents impacts from the opposing direction of travel). Since only one HTCB run is normally installed to protect both directions of traffic, the HTCB must prevent intrusion of opposing vehicles into the travel lane caused by the impact to the cable system on the back-side after crossing the centre of the median.

The test deflection and post spacing documented in the FHWA acceptance letters are based on the HTCB system being tested on tangent in a controlled environment for various proprietary products. The actual deflection may be greater under real life, site specific conditions (i.e. larger vehicles, variable impact angles, higher operating speeds, soil type/conditions, installation on curves, etc.). Therefore, it is desirable to provide a "desirable deflection space" consisting of the maximum specified deflection plus a safety margin between the HTCB and the median side painted yellow shoulder lines in both directions; and also between the HTCB and a median hazard if the HTCB is relied upon to protect vehicles from the hazard. The safety margin is to be determined by the Designer if applicable. Where practical, greater safety margins are desirable.

In particular locations, presumably of relatively short lengths, where the minimum safety margin cannot be provided, two possible alternative solutions can be considered.

One alternative is to install the HTCB on both sides of the median. This will resolve the "back hit" issue, but will double the cost.

The second alternative is to reduce the maximum specified deflection by reducing the post spacing, particularly where there are physical hazards (bridge piers, overhead sign posts, steep slopes, opposing vehicles, etc.). Most HTCB suppliers have charts correlating post spacing and deflection; estimated by interpolation between test results at certain post spacings. Before applying these charts, designers should ensure that these interpolations are acceptable to FHWA.

As previously indicated, longitudinal traffic barrier systems that are more forgiving are preferred. If there are no site constraints on a particular site or project (desirable deflection space available), designers can consider increasing the maximum post spacing and maximum specified deflection if the manufacturer's product has been accepted by FHWA. This will make the system more forgiving.

Line posts and terminal posts can be placed in sockets in concrete foundations or sockets driven into the ground depending on the soil condition, manufacturer's specification, FHWA acceptance letters and the recommendation of an Alberta registered professional engineer (specialized in foundation engineering or geotechnical engineering). Similarly, anchors require the same type of detailed engineering and acceptance based on generic crash testing as well as an engineering recommendation based on local soil information and other site conditions. Installation must allow for replacement of posts in original sockets after collision damage. Posts driven directly into the ground are not permitted.

5.4 HTCB Placement in Depressed Medians

Designers shall review the FHWA guidelines and acceptance letters, which stipulate rules for HTCB placement in depressed medians including guidelines about "off-limit" parts of the median where the HTCB should not be installed.

When there is an elevation difference between the roadways on a divided highway, cable barrier should typically be placed on the side of the median nearest the roadway with the higher elevation.

Shoulder vs. Ditch Placement

Although the installation of the HTCB in the ditch centre would tend to provide the largest desirable deflection space, the ditch soils are often relatively less compacted than the shoulder, the ditches are subject to water accumulation, and there are often structures in the median such as catch basins or culvert outlets. The ditches are often uneven, with weak soil conditions, and may require extra grading and compacting and review of the overall drainage patterns. These factors tend to make the ditch installation of HTCBs more expensive and the collision outcomes less predictable. The soils on median side slopes, on the other hand, are compacted, generally above the water table and, therefore, much stronger. Another disadvantage of the ditch location is that snow and ice can often submerge all or part of the cable barrier, thus rendering it less effective. HTCB located near the shoulder is generally not affected by snow drifts.

A survey of selective US State Departments of Transportation indicates that in the vast majority of cases shoulder installation is preferred for median HTCBs.

Therefore, **the preferred HTCB location is at the top of the median side slope near the shoulder**, subject to the FHWA guidelines listed below. HTCB should be installed in the ditch only when shoulder installations are not able to meet the desirable deflection space requirements. For ditch installations, the soil strength must be taken into account when designing the post foundations and end anchor foundations.
Where the existing sideslopes are unsuitable to allow installation of the barrier in the preferred location near the top of the median sideslope, the option of selective or general re-grading should be considered.

Installation on Median Sideslopes 6H:1V or Flatter (Refer to Drawing RDG-B2.1)

Where the median slope is 6H:1V or flatter, the preferred location is near the shoulder (as discussed above) however it is permitted to place the barrier down the slope (at an increased offset from the shoulder) provided it is not placed in the "no zone" (between 300mm and 2400mm from the toe of slope). This is to reduce the probability of vehicles under-riding the system.

Installation on Median Sideslopes between 6H:1V and 4H:1V (Refer to Drawing RDG-B2.2)

For depressed medians with slopes steeper than 6H:1V but flatter than 4H:1V, the

preferred location is on the sideslope within 1200 mm of the shoulder break point however this must be greater than 2400 mm away from the toe of slope.
- Another permitted location (although not preferred) is in the centre of the median ditch or within +/- 300 mm of the centre of the ditch.
- The option of two separate longitudinal runs of HTCB within 1200 mm from the edge of both shoulder breakpoints may also be considered where parts of the slopes are steeper than 4H:1V, the ditch is very narrow (not allowing the specified offsets and deflections) or there are fixed hazards in the median.

<u>Installation on Median Sideslopes Steeper than 4H:1V</u> (Refer to Drawing RDG-B2.3)
For depressed medians with slopes steeper than 4H:1V, HTCB typically may be placed under the following conditions:
- At the edge of the shoulder breakpoint (0 m lateral offset from shoulder).
- The option of two separate longitudinal runs of HTCB should also be considered where the median width is narrow, desirable deflection space cannot be met, general re-grading is not an option, etc.

5.5 Placement of HTCB on the Roadside (Refer to Drawing RDG-B2.4)
It is generally desirable to offset barrier systems as much as possible from the travelled way to reduce nuisance hits however designers must ensure that the space between the barrier system and any fixed hazards is at least equal to the design deflection. An additional factor of safety is desirable where feasible. HTCB systems can typically be placed down the sideslopes if the slopes are 4H:1V or flatter. This slope refers to the slope on the roadside between the shoulder break point and the barrier system (dimension “X1”). The area immediately behind the barrier system may be constructed at steeper slopes depending on the stability of the soil however a 0.6 m continuation of the flatter slope (behind the barrier) is desirable.

HTCB systems should not be placed down the slope on roadsides steeper than 4H:1V unless the system has been successfully crash tested under these conditions (with FHWA acceptance letter), however HTCB may be placed at the edge of pavement (or edge of shoulder on unpaved roads) as shown in the table below and on Drawing RDG-B2.4. Where the roadside sideslope is steeper than 4H:1V, the maximum dimension must be “X1” = 0 m.

Roadside Sideslope[1]	Maximum Dimension (X1) from the Outside Edge of Shoulder (m)[1]
6H:1V or flatter	Infinity
6H:1V > Sideslopes ≥ 4H;1V	0 to 1.2
Steeper than 4H:1V	0

[1] Refer to Geotechnical / Soil Conditions below

5.6 Placement on Curved Horizontal Alignments

Median and roadside HTCB installed on horizontal curves if hit on the convex side can be expected to have an increased deflection. Reducing the post spacing may be an effective countermeasure. Some agencies caution against using HTCB for convex curves if the radius is less than 160 m. Designers shall review the FHWA acceptance letters and the manufacturer and/or vendor's product details and specifications with respect to post spacing and test deflection. As indicated above, designers should note that the test deflection in the FHWA acceptance letters are normally based on the system being tested on tangent in a controlled environment. Actual test documentation on the post spacing and its effect on the test deflection on horizontal curves may not be available. Designers may have to review and rely on the supplier's interpolations of post spacing vs. deflection correlation as accepted by the FHWA acceptance letters, along with using good engineering judgement to determine the suitable post spacing.

There is generally a higher frequency of vehicles inadvertently leaving the roadway on the outside of horizontal curves versus the inside of horizontal curves. To reduce the frequency of low severity (nuisance) hits, the preferred location of a HTCB is towards the inside of the outermost horizontal alignment of a divided roadway. Refer to Figure 1.

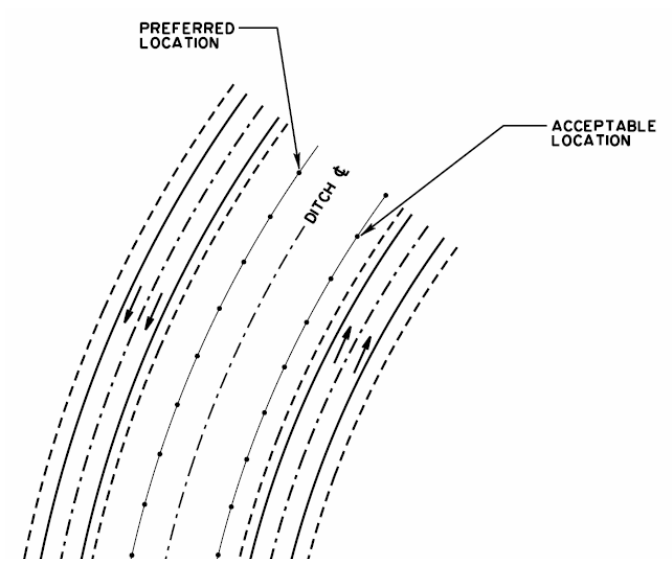


Figure 1: HTCB Placement on Horizontal Curves

5.7 Placement on Curved Vertical Alignments

HTCB placement may be restricted with respect to minimum vertical curvature based on the performance of the barrier system. Depending on the proprietary system chosen, typical minimum curvature values may vary. Designers shall review the FHWA acceptance letters and the manufacturer's product information and specifications for available details on minimum K values.

There may be restrictions on vertical sag alignments with small K values. According to FHWA/TX (Report No. 0-562009-2) reference to Alberson et al., some of the cable barrier systems have limited upward capability to carry vertical loads. As such, vertical sag curves may lift or partially lift the wire rope out of the post and increase the likelihood of vehicle under ride.

On socketed systems, there is generally no attachment of the posts to the sockets. Where the wire ropes are firmly attached to the posts, the wire rope may lift the post out of the socket on vertical sag curves and also increase the likelihood of vehicle under ride.

5.8 End Treatment or Anchors

End treatments that are exposed to on-coming traffic must terminate with a crashworthy end treatment that meets Test Level 3 (TL-3) crash test requirements of NCHRP 350 or MASH 2009. Where traffic is protected from cable barrier ends, non-crashworthy ends may be used. HTCB end terminals are proprietary.

5.9 Anchor Spacing - Run Length

The distance between anchor terminals is commonly referred to as a cable run or run length. In theory, there is no limit to the length of a single un-interrupted run of a cable barrier. However, longer cable runs require more effort to tension and re-tension, and there may be more maintenance/replacement difficulties with barriers that are very long. The presence of bridge structures at-grade intersections and emergency/maintenance crossovers would act as obvious breaks in cable barrier runs. A recommended maximum desired un-interrupted run of +/- 5 km was used on the median HTCB installation on Highway 2 from Airdrie to Red Deer.

Where a break or interruption in the cable run is required to meet the maximum desired un-interrupted run and where there is no convenient location (intersection or crossover) then a break and overlap in the HTCB alignment is required. The overlap should be a minimum of 10 m (not including the length of the anchor end terminals) or as per the manufacturer's specification.

For median at-grade intersections and emergency/maintenance crossovers, Alberta Transportation's practice has been to locate anchor end terminals a minimum of 15 m from the edge of the paved intersection or crossover to provide adequate space for snow storage.

5.10 Minimum Space between Parallel Barrier Systems

In some cases an existing barrier systems (i.e. concrete, W-Beam, or other) must remain in-place at a hazard (i.e. overhead sign post, bridge pier, sensor pole, etc.) while the HTCB system continues past along the shoulder of the roadway to retain continuity on either side of the hazard.

Where the HTCB runs parallel to an existing barrier system, the HTCB is providing double protection with an energy absorbing function. It is desirable that the spacing (offset) between the cable barrier and existing barrier system be enough to prevent the posts of the HTCB from becoming a hazard. Enough lateral space should be provided so that in the event the HTCB is knocked down by a vehicle, the posts do not impact the adjacent more rigid barrier system. A typical spacing of 0.9 m (desirable spacing > 1.0 m) has been used as a practice on Alberta Transportation projects. The minimum spacing will vary depending on the post details of the various proprietary products.

5.11 Overlapping Barrier Systems

When the HTCB system runs along the shoulder of the roadway, transitions to existing barrier systems are typically provided by overlapping the systems rather than physically connecting the two different barriers together. Although, physically connecting the two different types of barriers may produce a smoother transition, the efforts to retrofit an existing barrier system to support the required cable tension may be quite extensive, require additional maintenance and increased time to repair if impacted. Consequently, it is generally preferred to overlap the systems rather than connecting.

Where the HTCB is upstream of a segment of existing barrier (i.e. upstream of the crashworthy, flare and/or turndown end treatment), the HTCB should overlap in front of the existing system. The position of the HTCB would be between the paved shoulder and the face of the existing barrier system. The overlap length should be as long as possible, but meet the minimum space between the ends of the barrier systems and be at least the length of the end terminal section.

Where the HTCB is downstream of a segment of existing barrier, the HTCB should be positioned behind the existing barrier. The length of the overlap should be 5 m minimum, or preferably be 10 to 15 m.

Note: Where existing barriers are to remain in place, designers should also assess if the existing barrier system is in accordance with Alberta Transportation's current guidelines. The assessment may recommend reconstruction, replacement and or improvements to the existing barrier system.

5.12 Conditions Where Cable Barrier May Replace Existing Barriers

In general, HTCB may replace existing barriers where the HTCB system can maintain the desired alignment along the shoulder and pass by an existing hazard with a spacing (offset) greater than or equal to the desirable deflection (maximum specified deflection plus a safety margin) from the hazard.

5.13 Concrete Requirements for Post Foundations and/or Anchors

Concrete supply and placement shall meet all requirements of the "Specifications for Bridge Construction Section 4 - Cast-In-Place Concrete". Concrete shall be Class C Concrete 35 MPa.

5.14 Geotechnical Investigation / Soil Conditions

The soil condition in the field can be different than the soil condition used in the cable barrier tests on which the FHWA acceptances are based. Geotechnical investigations including the nature of the drainage must be carried out during the preliminary and/or early in the detailed design stage and the results included in the tender package. The ditch may also be subject to periodic flooding and/or wet soil conditions which must be taken into account in the design. The contractors/suppliers shall be responsible for the design and installation of the post foundations, concrete or steel footings and end treatments or anchors to the soil conditions on the site. The design shall be certified by a Professional Engineer experienced in structural/foundation design and registered with APEGGA.

6.0 EFFECTIVE DATE

The guidelines as indicated in this Bulletin are to be implemented immediately as per the usual practice.

Effective Date: February 7, 2012

7.0 CONTACT

Contact: Bill Kenny or Peter Mah, Technical Standards Branch, Alberta Transportation.

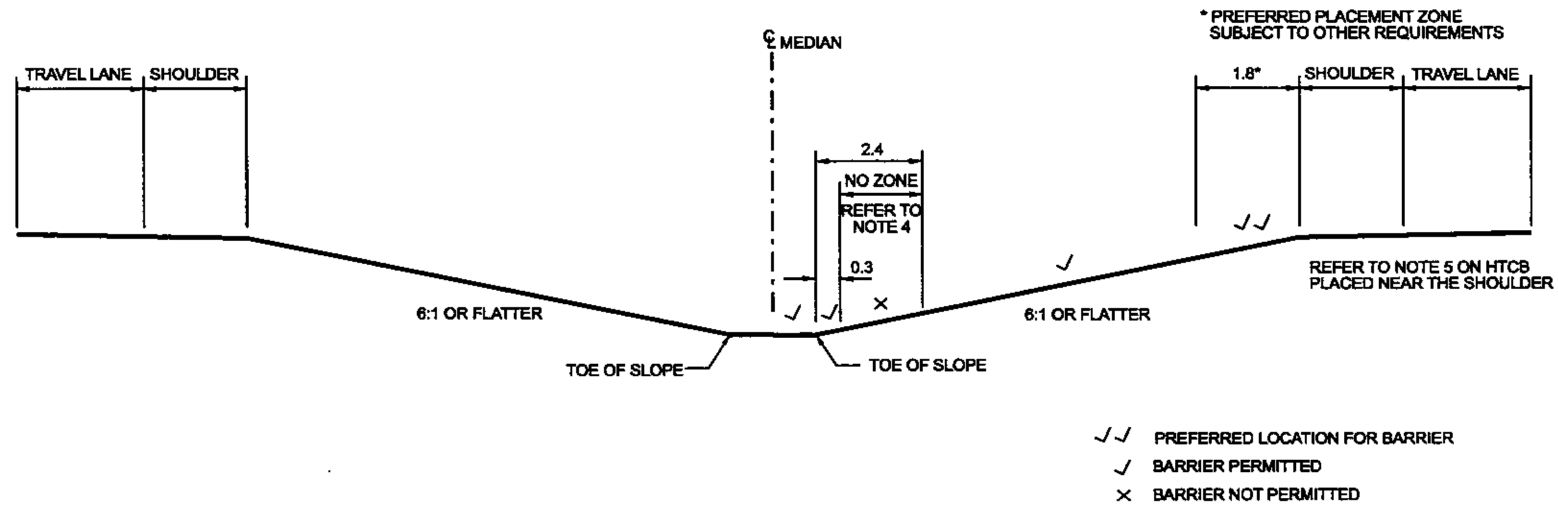
8.0 ATTACHMENTS

RDG-B2.1 Typical HTCB Median Installation, Slopes 6H:1V or Flatter
RDG-B2.2 Typical HTCB Median Installation, 6H:1V > Slopes ≥ 4H:1V
RDG-B2.3 Typical HTCB Median Installation, Slopes Steeper than 4H:1V
RDG-B2.4 Typical HTCB Roadside Installation

9.0 REFERENCES

Alberta Transportation - Roadside Design Guidelines, November 2007

Recommended:	Approved:
Bill Kenny, P.Eng.	for Moh Lali, P.Eng.
Director,	Executive Director,
Design, Project Management and Training	Technical Standards Branch
Date 7 Feb 2012	Date Feb. 17 2012



NOTES

1. HIGH TENSION CABLE BARRIERS (HTCB) ARE PROPRIETARY PRODUCTS AND THEREFORE MUST BE INSTALLED AND MAINTAINED IN ACCORDANCE WITH THE MANUFACTURER'S AND/OR VENDOR'S SPECIFICATIONS. CABLE BARRIER PRODUCTS VARY SUBSTANTIALLY IN DETAILS, SPECIFICATION AND METHOD OF INSTALLATION, ETC. DESIGNERS SHALL REVIEW THE FHWA (UNITED STATES FEDERAL HIGHWAY ADMINISTRATION) ACCEPTANCE LETTERS IN CONJUNCTION WITH THE MANUFACTURER /VENDOR'S PRODUCT DETAILS AND SPECIFICATIONS.

2. DESIGNERS SHALL REVIEW THE FHWA ACCEPTANCE LETTERS, AND THE TEST DOCUMENTATION UPON WHICH THE LETTER IS BASED IN DETAIL. THIS INCLUDES THE SUMMARY RESULTS (E.G. TEST DEFLECTION), TEST SITE CONDITIONS (E.G. POST SPACING, SOIL DATA, ETC.), PRODUCT DETAILS, PROVISIONS, ETC. IN WHICH THE PRODUCT WAS TESTED AND ACCEPTED UNDER.

3. FHWA ACCEPTANCE LETTERS ARE NORMALLY BASED ON THE HTCB SYSTEM BEING TESTED ON TANGENT IN A CONTROLLED ENVIRONMENT. THE SLOPE PLACEMENT, POST SPACING AND MAXIMUM SPECIFIED, DEFLECTION ETC, MAY NEED TO BE ADJUSTED DUE TO SITE SPECIFIC CONDITIONS.

4. ACCORDING TO FHWA GUIDELINES THE HTCB MAY BE PLACED IN THE MEDIAN DITCH; BUT WHEN PLACED ON THE MEDIAN SIDE SLOPE THE CABLE BARRIER TYPICALLY SHOULD NOT BE PLACED BETWEEN 300 mm AND 2400 mm FROM THE TOE OF THE SLOPE.

5. HTCB LONGITUDINAL RUNS ARE NORMALLY INSTALLED TO PROTECT BOTH DIRECTIONS OF TRAFFIC. HTCB PLACEMENT AND/OR DESIGN MUST PREVENT INTRUSION OF OPPOSING VEHICLES INTO THE TRAVEL LANE CAUSED BY THE IMPACT TO THE CABLE SYSTEM ON THE BACK-SIDE AFTER CROSSING THE MEDIAN.

6. NO ZONE. AREA IN THE MEDIAN WHERE HTCB TYPICALLY SHOULD NOT BE INSTALLED.

7. POSTS CAN BE PLACED IN SOCKETS IN CONCRETE FOUNDATIONS OR SOCKETS DRIVEN INTO THE GROUND DEPENDING ON THE SOIL CONDITION, MANUFACTURER'S SPECIFICATION AND FHWA APPROVALS. POSTS DRIVEN DIRECTLY INTO THE GROUND ARE NOT PERMITTED.

8. THE DITCH MAY BE SUBJECT TO WEAK SOILS (OFTEN UNCOMPACTED), PERIODIC FLOODING AND/OR WET SOIL CONDITIONS. THE SOIL STRENGTH MUST BE TAKEN INTO ACCOUNT WHEN DESIGNING THE POST FOUNDATIONS AND END ANCHOR FOUNDATIONS.

9. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.

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Approved:

For Executive Director, Technical Standards Branch

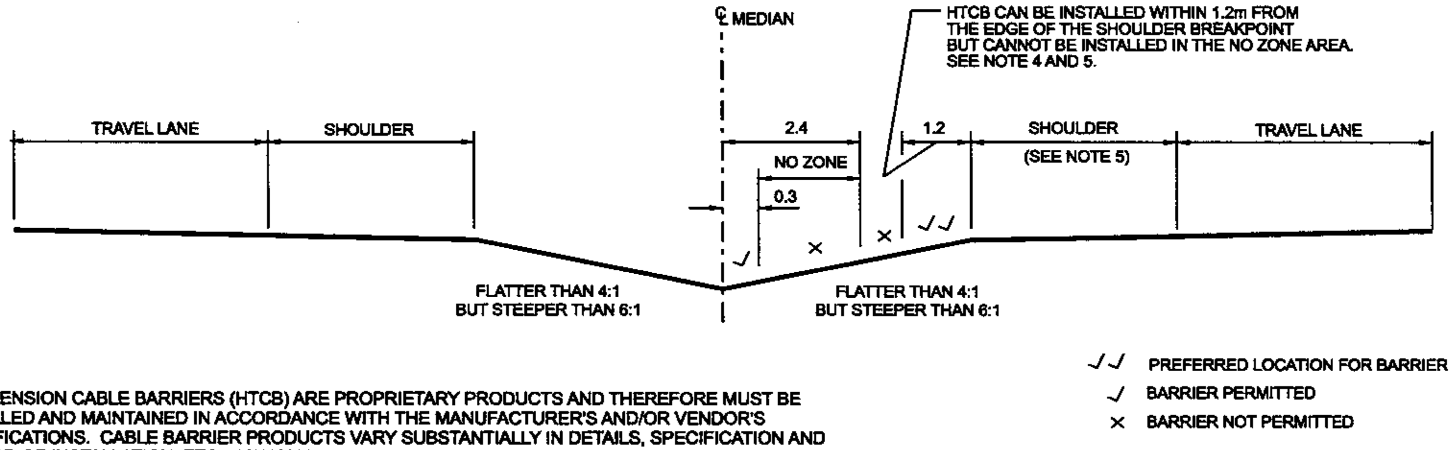
Date: Feb 17 2012

Government of Alberta ■ Transportation

TYPICAL HIGH TENSION CABLE BARRIER MEDIAN INSTALLATION

SLOPES 6(H):1(V) OR FLATTER

Prepared By:	Checked By:	Scale:	Dwg No.:
GEC.	PM	N.T.S.	RDG-B2.1



NOTES

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2. DESIGNERS SHALL REVIEW THE FHWA ACCEPTANCE LETTERS, AND THE TEST DOCUMENTATION UPON WHICH THE LETTER IS BASED IN DETAIL. THIS INCLUDES THE SUMMARY RESULTS (E.G. TEST DEFLECTION), TEST SITE CONDITIONS (E.G. POST SPACING, SOIL DATA, ETC.), PRODUCT DETAILS, PROVISIONS, ETC. IN WHICH THE PRODUCT WAS TESTED AND ACCEPTED UNDER.

3. FHWA ACCEPTANCE LETTERS ARE NORMALLY BASED ON THE HTCB SYSTEM BEING TESTED ON TANGENT IN A CONTROLLED ENVIRONMENT. THE SLOPE PLACEMENT, POST SPACING AND MAXIMUM SPECIFIED, DEFLECTION ETC, MAY NEED TO BE ADJUSTED DUE TO SITE SPECIFIC CONDITIONS.

4. ACCORDING TO FHWA GUIDELINES THE HTCB MAY BE PLACED AS FOLLOWS:
   - IN THE CENTRE OF A 4H:1V / 4H:1V MEDIAN DITCH OR WITHIN +/- 300 mm OF THE CENTRE OF THE DITCH;
   - WHEN PLACED ON THE MEDIAN SIDESLOPE THE CABLE BARRIER SHOULD BE WITHIN 1200 mm FROM THE EDGE OF THE SHOULDER BREAKPOINT BUT GREATER THAN 2400 mm AWAY FROM THE TOE OF SLOPE.
   - THE OPTION OF TWO SEPARATE LONGITUDINAL RUNS OF HTCB WITHIN 1200 mm FROM THE EDGE OF BOTH SHOULDER BREAKPOINTS SHOULD ALSO BE CONSIDERED WHERE THE ABOVE BARRIER PLACEMENT CONDITIONS AND/OR DESIRABLE DEFLECTION CANNOT BE MET, SELECTIVE OR GENERAL RE-GRADING IS NOT AN OPTION, ETC.

5. HTCB LONGITUDINAL RUNS ARE NORMALLY INSTALLED TO PROTECT BOTH DIRECTIONS OF TRAFFIC. HTCB PLACEMENT AND/OR DESIGN MUST PREVENT INTRUSION OF OPPOSING VEHICLES INTO THE TRAVEL LANE CAUSED BY THE IMPACT TO THE CABLE SYSTEM ON THE BACK-SIDE AFTER CROSSING THE MEDIAN.
   - THE OPTION OF TWO SEPARATE LONGITUDINAL RUNS OF HTCB WITHIN 1200 mm FROM THE EDGE OF BOTH SHOULDER BREAKPOINTS SHOULD ALSO BE CONSIDERED WHERE THE ABOVE BARRIER PLACEMENT CONDITIONS CANNOT BE MET AND/OR WHERE SELECTIVE OR GENERAL RE-GRADING IS NOT AN OPTION.

6. NO ZONE. AREA IN THE MEDIAN WHERE HTCB TYPICALLY SHOULD NOT BE INSTALLED.

7. POSTS CAN BE PLACED IN SOCKETS IN CONCRETE FOUNDATIONS OR SOCKETS DRIVEN INTO THE GROUND DEPENDING ON THE SOIL CONDITION, MANUFACTURER'S SPECIFICATION AND FHWA APPROVALS. POSTS DRIVEN DIRECTLY INTO THE GROUND ARE NOT PERMITTED.

8. THE DITCH MAY BE SUBJECT TO WEAK SOILS (OFTEN UNCOMPACTED), PERIODIC FLOODING AND/OR WET SOIL CONDITIONS. THE SOIL STRENGTH MUST BE TAKEN INTO ACCOUNT WHEN DESIGNING THE POST FOUNDATIONS AND END ANCHOR FOUNDATIONS.

9. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.

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Approved:
Executive Director,
Technical Standards Branch

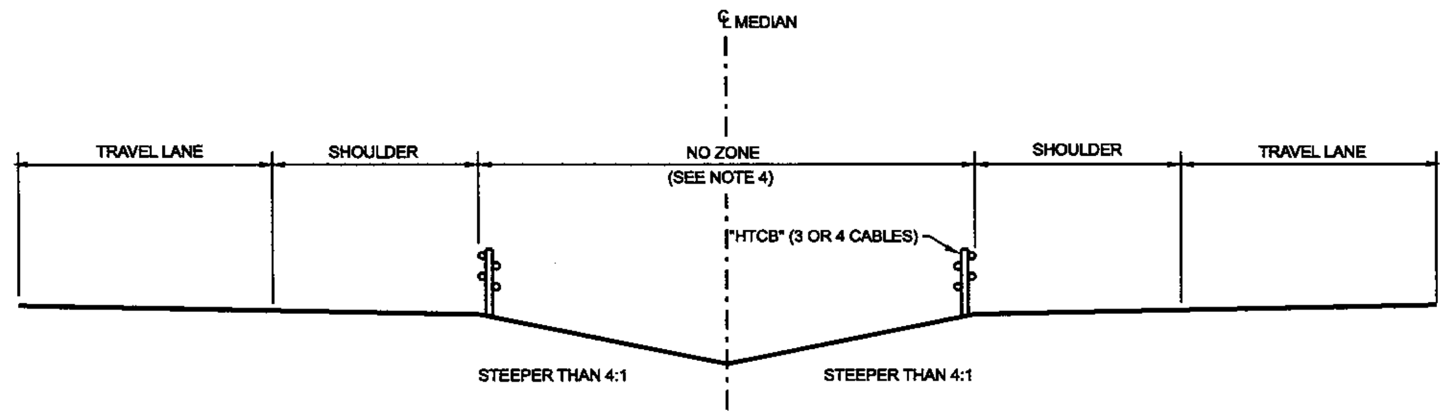
Date: Feb 17 2012

Government of Alberta
Transportation

TYPICAL HIGH TENSION CABLE BARRIER MEDIAN INSTALLATION

6(H):1(V)> SLOPES ≥ 4(H):1(V)

Prepared By: GEC.	Checked By: PM	Scale: N.T.S.	Dwg No.: RDG-B2.2



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4. HTCB TYPICALLY SHOULD BE PLACED UNDER THE FOLLOWING CONDITIONS:
   - AT THE EDGE OF THE SHOULDER BREAKPOINT (0 m LATERAL OFFSET).
   - THE OPTION OF TWO SEPARATE LONGITUDINAL RUNS OF HTCB SHOULD ALSO BE CONSIDERED WHERE THE MEDIAN WIDTH IS NARROW, DESIRABLE DEFLECTION SPACE IS GREATER THAN THE SHOULDER WIDTH, AND/OR GENERAL RE-GRADING IS NOT AN OPTION, ETC.
5. NO ZONE. AREA IN THE MEDIAN WHERE HTCB TYPICALLY SHOULD NOT BE INSTALLED.
6. POSTS CAN BE PLACED IN SOCKETS IN CONCRETE FOUNDATIONS OR SOCKETS DRIVEN INTO THE GROUND DEPENDING ON THE SOIL CONDITION, MANUFACTURER'S SPECIFICATION AND FHWA APPROVALS. POSTS DRIVEN DIRECTLY INTO THE GROUND ARE NOT PERMITTED.
7. THE DITCH MAY BE SUBJECT TO WEAK SOILS (OFTEN UNCOMPACTED), PERIODIC FLOODING AND/OR WET SOIL CONDITIONS. THE SOIL STRENGTH MUST BE TAKEN INTO ACCOUNT WHEN DESIGNING THE POST FOUNDATIONS AND END ANCHOR FOUNDATIONS.
8. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.

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Approved: [signature]
For Executive Director,
Technical Standards Branch

Date: Feb 17 2012

Government of Alberta ■
Transportation

TYPICAL HIGH TENSION CABLE BARRIER MEDIAN INSTALLATION
SLOPES STEEPER THAN 4(H):1(V)

Prepared By: GEC.	Checked By: PM	Scale: N.T.S.	Dwg No.: RDG-B2.3

NOTES

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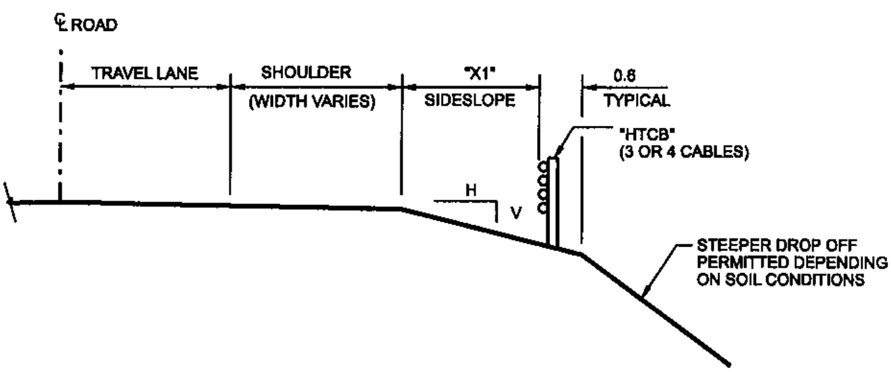
4. HTCB SYSTEMS CAN TYPICALLY BE PLACED DOWN THE SIDESLOPES IF THE SLOPES ARE 4H:1V OR FLATTER. THIS SLOPE REFERS TO THE SLOPE ON THE ROADSIDE BETWEEN THE SHOULDER BREAK POINT AND THE BARRIER SYSTEM (DIMENSION "X1"). THE AREA IMMEDIATELY BEHIND THE BARRIER SYSTEM MAY BE CONSTRUCTED AT STEEPER SLOPES DEPENDING ON THE STABILITY OF THE SOIL.

5. HTCB SYSTEMS SHOULD NOT BE PLACED DOWN THE SLOPE ON ROADSIDES STEEPER THAN 4H:1V UNLESS THE SYSTEM HAS BEEN SUCCESSFULLY CRASH TESTED UNDER THESE CONDITIONS (FHWA ACCEPTANCE LETTER), HOWEVER HTCB MAY BE PLACED AT THE EDGE OF PAVEMENT (OR EDGE OF SHOULDER ON UNPAVED ROADS) AS SHOWN IN THE TABLE.

6. ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE NOTED.



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ROADSIDE SIDESLOPE*	MAXIMUM DIMENSION (X1) FROM THE OUTSIDE EDGE OF SHOULDER (m) *
6H:1V OR FLATTER	INFINITY
6H:1V > SIDELSOPES ≥ 4H: 1V	0 TO 1.2
STEEPER THAN 4H:1V	0

*SUBJECT TO GEOTECHNICAL/SOIL CONDITIONS

Approved:

[signature]

Executive Director,
Technical Standards Branch

Date: Feb 12 2012

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Transportation

TYPICAL HIGH TENSION CABLE BARRIER ROADSIDE INSTALLATION

Prepared By:	Checked By:	Scale:	Dwg No.:
GEC	PM	NTS	RDG-B2.4