APPENDIX E

GUIDELINES FOR THE SELECTION AND DESIGN OF HIGH TENSION CABLE BARRIER SYSTEMS

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Appendix E
Guidelines for the Selection and Design of High Tension Cable Barrier Systems

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APPENDIX E1
HTCB PRODUCTS LIST AND ACCEPTANCE TESTING

HE1.1 Alberta Transportation Product Development and Acceptance Testing

The Alberta Transportation Products List of proven, trial and potential products for HTCB (including vendor information) is available at the link indicated below. There are currently four suppliers of proprietary HTCB on the Products List (Traffic Control Devices) dated September 8, 2016.

http://www.transportation.alberta.ca/689.htm

HE1.2 Testing and Approval of HTCB under NCHRP Report 350 and/or MASH 2009

As of September 8, 2016 there are five proprietary HTCB systems in North America that have passed NCHRP 350 and/or MASH 2009. They are listed below in alphabetical order. Not all of the tested systems are on the Alberta Transportation Products List.

- Brifen Canada
  15521 Marine Drive
  White Rock, BC V4B 1C9, Canada
  http://www.brifen.ca

- Gibraltar
  4303 Innovation Loop
  Marble Falls, TX 78654, USA
  http://gibraltarus.com

- Nucor Steel Marion, Inc.
  912 Cheney Avenue
  Marion, Ohio 43302, USA
  http://www.nucorhighway.com
  (Note: Not on Alberta Transportation's Products List dated September 8, 2016)

- SAFENCE (Gregory Industries, Inc.)
  4100 13th Street, SW
  Canton, Ohio 44710, USA
  http://www.gregorycorp.com

- Trinity Highway Safety Products
  2525 North Stemmons Freeway
  Dallas, Texas 75207, USA
  http://www.highwayguardrail.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. 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. The test results are submitted by the suppliers to the US Federal Highway Administration (FHWA) which then issues Eligibility Letters (previously referred to as "Acceptance Letters") based on the test results, for the individual systems. The FHWA issues the letters to developers, manufacturers and other petitioners recognizing their certifications that the hardware they represent have been crash tested and meet the appropriate crash testing criteria. FHWA letters identify, among other things, the major properties of the HTCB system such as test post spacing and test deflection. The letters also include or refer to various FHWA and American Association of State Highway and Transportation Officials (AASHTO) guidelines and caveats for the placement and installation of the particular system being accepted.

Previously, all longitudinal barriers accepted for highway application were required to meet the test conditions stated in the Transportation Research Board (TRB) National Cooperative Highway Research Program (NCHRP) Report 350, *"Recommended Procedures for the Safety Performance Evaluation of Highway Features*" 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. TL-6 substitutes a 36,000-kg tractor/tank trailer.

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

The 2009 "*Manual for Assessing Safety Hardware*" (MASH 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 highway safety devices. 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.

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 a

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. 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. There is no accepted HTCB for installation on side slopes steeper than 4H:1V.

The information above pertains to installations on median or roadside (non-median) locations.

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APPENDIX E2
GENERAL DESIGN PROCESS

HE2.1 Introduction

The following sections describe the suggested design process for HTCB systems. For specific design guidelines, refer to Section **H5.5.2**. The interactive nature of the various design elements and the physical site characteristics may necessitate an iterative design approach.

HE2.2 General Design Process

HE2.2.1 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 Eligibility Letters issued for individual HTCB systems and products. The FHWA Eligibility 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 and guidelines as well as 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 Eligibility 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 for Safety, on the subject of "*INFORMATION: Cable Barrier Considerations*". (Ref 2) Designers should therefore contact FHWA to obtain the latest information regarding HTCB-related Eligibility Letters and guidelines.

Designers should review the FHWA Eligibility 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. under which the product was tested and accepted.

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 should review the FHWA Eligibility Letters in conjunction with the manufacturer and/or vendor's product details and specifications.

When reviewing the FHWA Eligibility Letters and the suppliers' literature, the following are some of the factors that should be kept in mind:

- More than one FHWA Eligibility 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 spacing. 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 acceptances were based on tests on level ground. However, in the tests on a 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. 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. There is no accepted HTCB for installation on side slopes steeper than 4H:1V. 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.

HE2.2.2 Compile the Physical Characteristics of the Project Site

The lateral placement of the HTCB 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 taken during the survey/preliminary 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 a geotechnical investigation conducted during the preliminary design phase. Of particular interest are items such as median width, shoulder width, side slopes, protected as well as unprotected hazards, existing barriers and the presence of transverse or longitudinal utilities.

HE2.2.3 Determine Space Availability for HTCB Deflection, Required Test Level (3 or 4) and Cable Configuration (3 or 4)

Designers must assess the deflection room available for safe operation of the HTCB system.

HTCB's are generally not suitable for very narrow medians (normally the median width should exceed twice the width of the design 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 median width does not exceed twice the width of the design deflection. 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 a reduction of collision numbers or collision severity.

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 details, in Section **H5.5.2**, for details of slope constraints.

For roadside (non-median) 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). 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. There are a variety of cable heights among the various cable barrier system designs tested under NCHRP 350 criteria. Current research efforts are considering whether these cable heights will be adequate to accommodate the larger pick-up truck which is defined in 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 are specified for Alberta Transportation projects. Cables are pre-stretched 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 FHWA has indicated that "pre-stretched cables have advantages including reduced dynamic deflection by reducing the "play" between the individual wire strands in the bundle that forms the cable prior to installation." (Ref 2)

HE2.2.4 Ensure Competitive Bidding

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

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

- Within the constraints posed by the physical characteristics of the project, it is desirable that designers set the specified maximum deflection (design deflection) at a value equal to, or greater than, the highest test deflection among the eligible accepted systems.

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 specified maximum deflection was set at 2.4 metres, based on FHWA's 6H:1V Eligibility Letters. This allowed several suppliers to potentially bid on the project.
- On the Highway 2 median HTCB project, the median sideslope varied from 6H:1V to 4H:1V. On the basis of FHWA's 4H:1V Eligibility Letters, the specified maximum deflection was set at 2.7

metres. This allowed at least two suppliers to potentially bid on the project; one had a test deflection of 2.6 metres and the other had a test deflection of 2.7 metres. A third supplier's test deflection of 3.7 metres was ruled out of consideration as being too high.

HE2.2.5 Specify the Design Criteria and Considerations

It is recommended that design criteria and considerations unique to the project be tabulated for use in the design. The following is a list of items that are typically included (there may be other items), in a Design Criteria and Considerations Table.

DESIGN CRITERIA and CONSIDERATIONS TABLE (EXAMPLE ONLY)	
Item	**Design Criterion**
Installation Type (Roadside or Median)	
Cable Barrier Type (TL-3 or TL-4)	
Road Width	
Sideslope	
3-Cable or 4-Cable	
Hazard Offset	
Specified Maximum Deflection (Design Deflection)	
Desired Deflection Space	
Minimum Space Between Parallel Barrier Systems	
Transition Between Barrier Systems	
Minimum Overlap Between Ends of Barrier Systems	
Locations Where Cable Barrier could replace Existing Barrier Systems	
Offset from Edge of Roadway	
Placement on Horizontal Curves	
Median Crossovers for Emergency and/or Maintenance Access	
At-Grade Intersections	
Subsurface Investigation	
Choice of End Terminal Anchor	
Possible Requirement for Selective Grading	
Other	

HE2.2.6 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.

HE2.2.7 Package the Tender

Ensure that the Unit Price Schedule and Special Provisions (including a table identifying locations for installation) reflect the requirements of the project.

To allow for a competitive bidding environment, specify the HTCB technical and performance requirements rather than naming a particular product. The objective is to ensure that as many suppliers as possible (with accepted products) are able to bid on the HTCB contracts.

HE2.2.8 References

Ref 2) FHWA, "*Information Memorandum: Cable Barrier Considerations*", July 20, 2007
http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/policy_memo/memo072007/

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