Index D450 High Tension Cable Barrier

Design Criteria

Plans Preparation Manual (PPM) Volume 1, Chapter 4; ***AASHTO Roadside Design Guide***, 4th Edition, ***NCHRP Report 711*** - Guidance for the Selection, Use, and Maintenance of Cable Barrier Systems, 2012, ***NCHRP Report 350***, Test Level 4 Criteria, ***AASHTO Manual for Assessing Safety Hardware (MASH)***, 2009, Test Level 4 Criteria

Design Assumptions and Limitations

High Tension Cable Barrier (HTCB) is a supplementary barrier to those provided in the ***PPM***, Volume 1, Chapter 4, for use on limited access facilities to reduce median crossover crashes or to protect against continuous longitudinal roadside hazards (e.g. canal hazards). As a flexible barrier system, HTCBs have greater deflections than the various guardrail (semi-rigid) configurations or concrete barriers (rigid). This flexibility generally allows HTCB systems to absorb and distribute more impact energy than the semi-rigid and rigid alternatives while effectively containing and redirecting vehicles. Although HTCBs require larger lateral offsets to provide deflection space, the systems are typically installed farther away from the edge of traffic which allows errant vehicles more room to regain control and avoid nuisance impacts.

HTCB is not intended for protection of point source hazards (e.g. overhead sign structures and bridge piers).

HTCBs are proprietary systems with varying end terminal assemblies, general length of need segments, hardware and foundations. As such, the design of the system components, end terminal anchor foundations, line post foundations, and overall layout will be provided by the Manufacturer or Contractor's Specialty Engineer.

Only HTCB systems on slopes 1:6 or flatter that have been crash tested in accordance with ***NCHRP Report 350*** or ***MASH*** to Test Level 4 (TL-4) and have been issued a FHWA Eligibility Letter are approved for use. HTCB systems that meet the requirements of ***Developmental Specifications*** Section 540 have been included on the Department's Innovative Products List (IPL) website. Although the EOR will not chose the specific proprietary system to be used, they must become familiar with the IPL Drawings of each system. Including; deflection characteristics, line post spacing, end terminal assembly lengths and any limitation thereof. This familiarity is important because certain design conditions may require project specific restrictions for some systems (e.g. line post spacing limits or minimum lateral offsets), which will need to be detailed in the Plans.

Line Post Foundation designs are included on the Manufacturer's IPL drawings. The designs include an alternative size/configuration for locations where the estimated seasonal high groundwater is below the bottom of the line post foundation (unsaturated condition) and another for locations where short-term water levels are at the ground surface (saturated condition). These Line Post Foundation designs are based on the following criteria, which covers the majority of soil types found in Florida:

Classification = Cohesionless (Fine Sand)

Friction Angle = 30 Degrees

Moist Unit Weight = 112 lbs./cu. ft.

Effective Unit Weight = 50 lbs./cu. ft.

In cases where the EOR considers the soil at the specific site location(s) to be of lesser strength, project specific designs will be required from the HTCB systems manufacturer or the Contractors Specialty Engineer. Additional system and contractor-responsible design requirements are included in ***Developmental Specifications*** Section 540.

HTCB Selection and Placement Guidelines

To aid the EOR and ensure consistency in the design approach the following Selection and Placement Guidelines have been developed.

A. HTCB System Selection - Use HTCB only upon the completion of an analysis following the recommendations included in the ***AASHTO Roadside Design Guide*** and the ***PPM***. At a minimum the analysis should include an evaluation of the following:

- The median width
- Type of median and terrain (flush or depressed, steepness of side-slopes, and drainage features)
- Traffic volume, including estimated traffic growth and percent trucks
- Crash history, specifically crossover collisions
- Design Speed
- Facility access points
- Median crossover locations, including potential elimination or addition thereof
- Roadway alignment and geometry
- Lateral clear space between hazards and edge of traveled way
- Suitability of alternative barrier types (i.e. guardrail and concrete barrier wall)

If recommend for use, include in the analysis the proposed location of the HTCB. Final approval for use of HTCB will be provided by the District Roadway Design Engineer.

The EOR will then be responsible for final design considerations and placement of HTCB in the contract plans. Placement criteria are included in the following paragraphs, and based on the limitations and recommendations provided in ***NCHRP Report 711***.

B. Slope Considerations - The ideal slope placement considerations, listed in order of preference, are as follows:

1. Where possible, locate HTCB on relatively flat, unobstructed terrain with a slope of 1:10 or flatter.

2. Locate on shoulders or median cross-slopes up to 1:6.
3. If slopes steeper than 1:6 exist and barrier is needed, consider regrading the slopes to meet either of the above recommendations or place fill to create a split level (bifurcated) concrete median barrier.
4. If regrading or other options are not feasible, placement on slopes up to 1:4 may be considered. Proposed installations on slopes steeper than 1:6 must be approved by the State Roadway Design Engineer.

Commentary: Installation on slopes between 1:6 and 1:4 have only been crashed tested to Test Level 3 requirements, which should be considered when evaluating suitability of barrier type alternatives and location.

C. Length of Need - Determine the necessary Length of Need for a run of HTCB based on the Minimum and Maximum Length recommendations below, with consideration for Median Crossovers (Emergency/Maintenance Openings) or any other limitations as described herein. When HTCB is placed to shield a roadside hazard locate the Being/End Length of Need in a similar manner to guardrail (See ***IDS*** for ***Design Standards*** Index 400).

Commentary: HTCB systems are comprised of a Length of Need Segment (General HTCB, Index D450) and an End Terminal Assembly at each end of the barrier run. HTCB is primarily intended for use as a means of reducing median crossover crashes, and as such, the Length of Need segment of an individual run of barrier is generally determined based on the occurrence of conditions which would precipitate those types of crashes. End Terminal Assemblies are considered gating (allow vehicles to pass through), and not considered as part of the Length of Need.

D. Minimum Length - The preferred minimum overall length (end anchor to end anchor) of a HTCB system is 1,000 feet.

Commentary: HTCB crash testing has only been conducted on segments 300 feet and greater. Therefore, overall lengths of less than 300 feet will not be permitted. If less than 300 feet of space is available an alternative barrier type should be used due to the reduced re-directional capability of the system.

E. Maximum Length - Maximum systems lengths vary by installation and is dependent on vertical curvature, horizontal alignment, and other potential site constraints. Systems installed within fairly flat terrain and relatively straight alignments can be extended for lengths in excess of 10,000 feet. When end terminal protection is not provided (See Paragraph G, End Terminal Placement & Protection) and the system is located within the Clear Zone of any traffic lane, consideration should also be given to reducing the maximum length of barriers runs to 1 mile, or less.

Commentary: Evaluate potential system length restrictions in areas where deflection limits need to be tightly controlled due to limited clear space. Reducing the length of individual barrier runs prevents long sections of barrier from being disabled if an end terminal is struck by a vehicle and the cables lose tension.

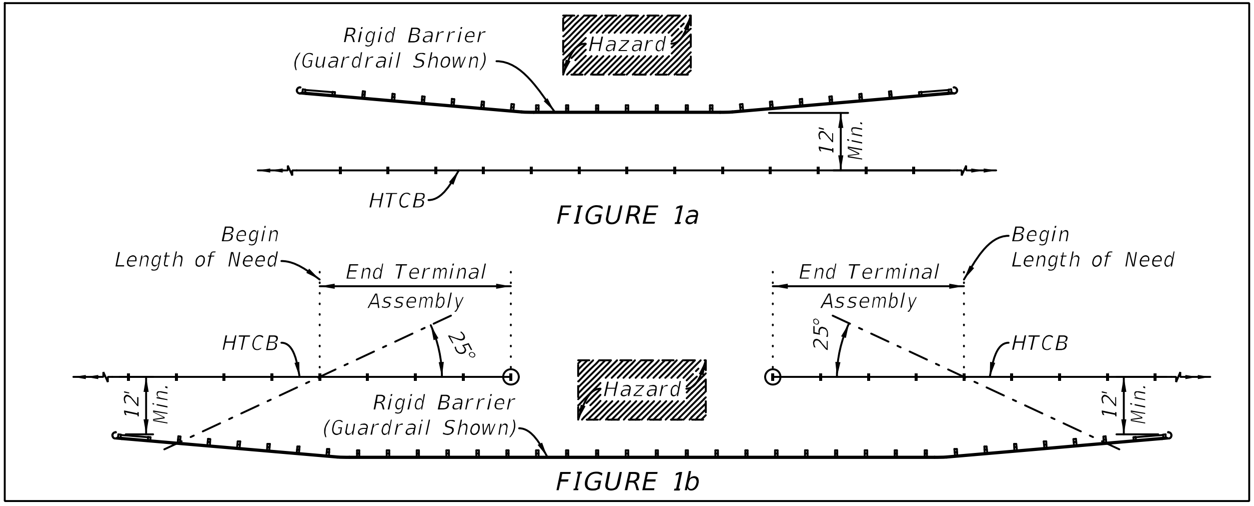
F. Lateral Placement - Preferably, HTCB should be installed as far from traffic as possible to allow ample deflection space between opposing traffic lanes and reduce the potential for nuisance impacts. Avoid where possible the placement of HTCB at the bottom of ditches or toe of slopes when surface water runoff or drainage features exist. For slopes of 1:6 or flatter follow the HTCB Lateral Offset limits shown on ***Developmental Design Standards*** Index D450.

Additionally, consideration should be given to the following when determining to proper lateral placement (offset):

- The preferred minimum offset from any Edge of Travel Lane or crashworthy barrier/structure (e.g. guardrail, concrete barrier wall, sign supports) is 12 feet.
- HTCB should not be used to shield above ground hazards, such as bridge piers or overhead sign structures. At those locations other more rigid barriers should be used (i.e. guardrail or concrete barrier wall) as shown in Figure 1.
- When approved for use on slopes between 1:6 and 1:4, follow the lateral placement guidelines provided in ***NCHRP Report 711***.
- In non-symmetric medians, it is preferable to locate the HTCB on the side of the median with the flatter slope.
- If installed in roadway sections with superelevation steeper than 3 percent, locate the barrier no farther than 5 feet from shoulder break point or locate on the opposite side of the median.
- Placement of the barrier should also take into consideration avoidance of drainage features or other utilities located/buried within the median.

Commentary: The dynamic deflection of HTCB systems during impacts is an important component of its evaluation and design. Proper barrier installations require adequate clear space between the barrier and opposing hazards to accommodate the anticipated dynamic deflection. The deflection of the HTCB system is also dependent on the end anchor spacing, cable tension, and posting spacing, as discussed herein.

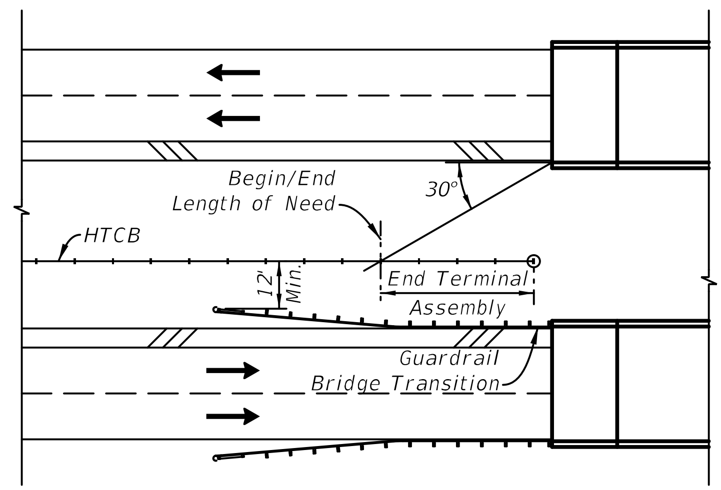
Figure 1 Shielding of Above Ground Hazards



G. End Terminal Placement & Protection - Placement of the end terminals must account for the variability of the different proprietary systems available and allow for end anchor foundation placement within the space available. The HTCB End Terminal Assemblies are evaluated through crash testing and considered crashworthy. However, when conditions permit, protect the End Terminal Assemblies from impacts by placing them behind another barrier, such as guardrail at bridge ends (See Figure 2). Installing barriers for the sole purpose of protection the HTCB end terminal assembly is not required.

Commentary: Limitations on some systems may be necessary if the Length of Need required does not provide enough space for a particular manufacturers End Terminal Assembly. Although the end terminals are crashworthy, protection is ideal because the cables lose tension when impacted in the approach direction at the termination posts (i.e. head-on impact on the upstream end).

Figure 2 End Terminal Protection (Bridge End)



H. Vertical Curve Placement - Consider the following to reduce adverse cable forces and prevent system damage or post pull-out:

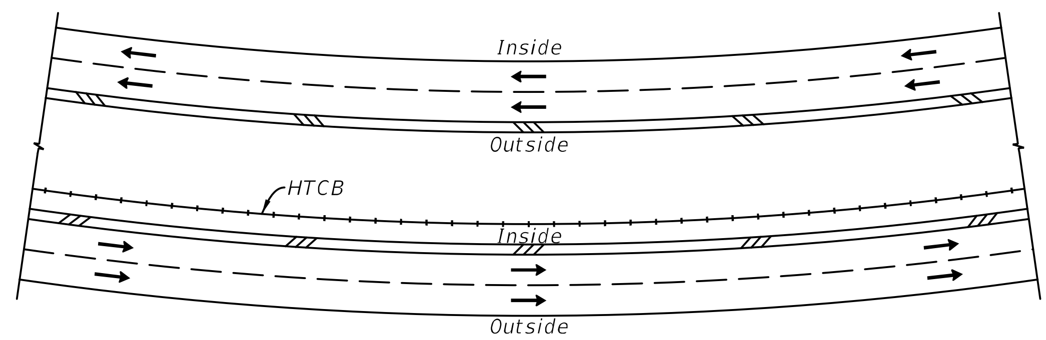
1. Place end anchors as close as possible to the minimum and maximum points of vertical curvature.
2. Place end anchors at locations of sudden change in vertical slope.
3. Reduce post spacing in areas of sharp vertical curvature.
4. Regrading short sections of median to remove sharp vertical curves.

Commentary: HTCB placed within vertical curves may create adverse (upward or downward) forces on the line posts from the tension in the cable. This is typically most impactful when the end terminal anchor(s) are located at a higher elevation than the general line post segments in sag vertical curves. Under these conditions the tension forces exert an upward force on the line posts as the cables attempt to become taut. Depending on the specific manufacturer's system, these forces could *pull the line posts out of the sockets, pull the cable from the post, or pull foundations away from the soil, which would result in less cable tension or improper cable heights.*

I. Horizontal Curve Placement - Since roadway departures are more common in horizontal curves, in particular to the outside of the curve (concave side), the preferred location of HTCB along horizontal curves is closer to the opposing lanes (convex side) as shown in Figure 3. Also, decreased line post spacing is effective in reducing the lateral load and deflection, and should be considered within horizontal curves having a radius of less than 1,300 feet.

Commentary: When cable barrier is located in horizontal curves the tension forces may exert excessive lateral forces, which may result in long-term bending of the line posts. Additionally, when curved cable barrier is impacted, the tension in the HTCB system is immediately reduced as the cable separates from the line posts and becomes slack. The loss in the cable tension will result in dynamic deflections in excess of the barrier's design deflection.

Figure 3 Horizontal Curve Placement



J. Line Post Spacing - Consider the following maximum line post spacing to account for inherent limitations in system performance:

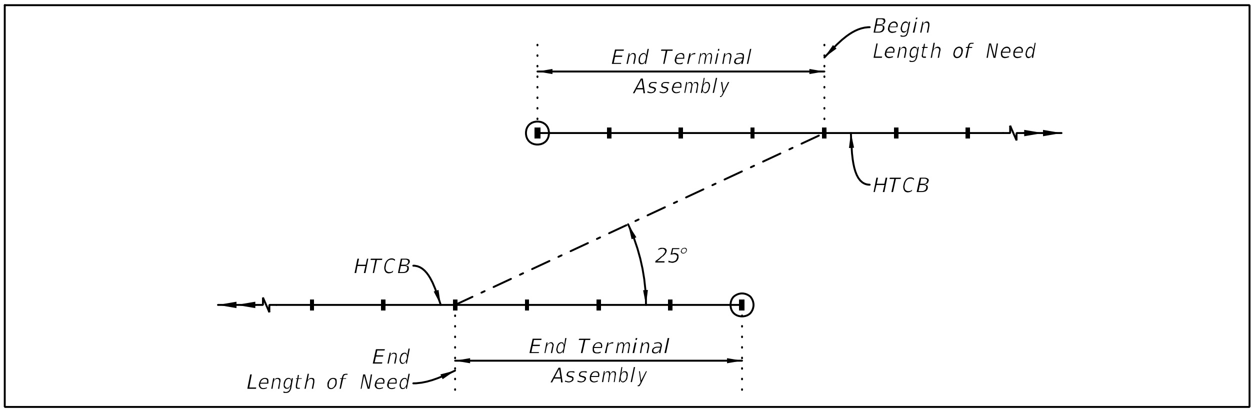
1. Locations outside of the clear zone of any travel lane - 16 feet
2. Locations within the clear zone of any travel lane - 10 feet
3. Locations on slopes steeper than 1:6 - 10 feet

Commentary: Line post spacing is a significant factor in the performance of HTCB (i.e. shorter spacing results in less dynamic deflection). The deflection and containment ability is expected to be more consistent when the post spacing is limited. It is also important to understand that crash-testing is performed on lengths of barrier that are much shorter (300 to 600 feet) than most practical installations and specific deflections measured during testing should not be anticipated for longer runs of barrier. Calibrated computer simulations have been used to estimate barrier *deflections of longer cable runs; however, due to the inherent variability of impacts outside of controlled crash-tests, tighter post spacing is recommended for areas where deflection limits are of specific concern (e.g. narrow medians or horizontal curves).*

K. Barrier Overlap - At locations where the HTCB switches from one side of the median to the other or at locations where cable barrier anchors are determined necessary as a result of other system constraints (e.g. length limitations or vertical curve concerns), the End Terminal Assemblies should be overlapped to shield the anchorages from errant vehicles crossing the median (See Figure 4).

Commentary: Overlap is recommended to reduce the risk of disabling adjacent runs of barrier if an end anchorage is impacted. Gradual switches (tapers) in HTCB location from one side of the median to the other may be used along straight level segments of roadway. However, do not taper HTCB towards the direction of traffic (i.e. taper away from the direction of traffic).

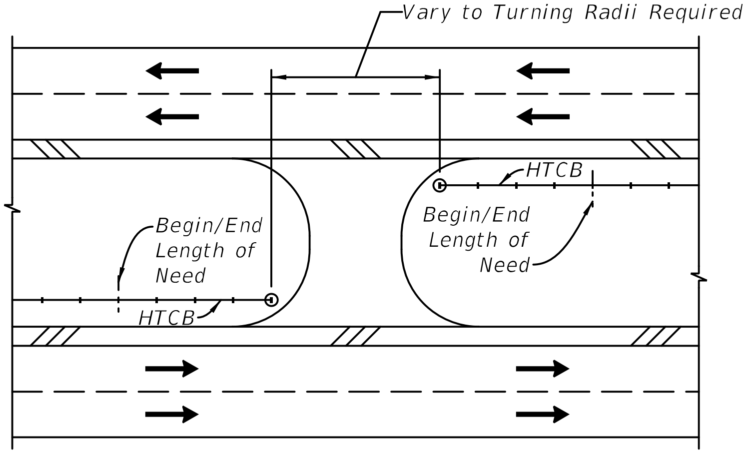
Figure 4 HTCB Overlap or Wide Median Crossover



L. Median Crossover - Meet the requirements of ***PPM***, Volume 1, Chapter 2, Section 2.14.4, for permanent Median Crossovers. Overlap the End Terminal Assemblies where median widths allow for adequate maneuverability between the HTCB (Wide Median) as shown in Figure 4.

At locations were the median width will not allow for turning movements between the separate runs of HTCB (Narrow Median), terminate the barriers on opposite sides of the median as shown in Figure 5.

Figure 5 Narrow Median Crossover



M. Mow Strips - Mow strips for HTCB should be either 3-inch thick unreinforced concrete or 2-inch thick miscellaneous asphalt. The 3-inch thick concrete mow strip is required for HTCB located within one foot of a ditch bottom or toe of slope (See ***Developmental Design Standards*** Index D450).

Additionally, at locations where saturated soil conditions (See Paragraph N, Soil & Groundwater Conditions) are of concern, consider a concrete mow strip to help provide additional rigidity of the line post foundations. At all other locations 2-inch thick miscellaneous asphalt may be used.

Commentary: Mow strips are typically required to prevent vegetation growth and reduce maintenance operations in close proximity to traffic barriers. However, under certain installation conditions mow strips, in particular concrete mow strips, help improve barrier containment performance. This is accomplished by providing a rigid surface below the flexible HTCB system so that vehicles will be less likely to gouge the ground surface and under-ride the barrier.

N. Soil & Groundwater Conditions - Do not place HTCB in locations where the seasonal high groundwater is at or above the proposed ground surface. Locating HTCB in areas with a seasonal high groundwater level less than one (< 1.0) foot below the proposed final grade is not recommended. During the design phase a geotechnical investigation and evaluation is required to provide the Contractor sufficient information to bid, design, and construct the HTCB system in accordance with ***Developmental Specifications*** Section 540. Evaluate the soil and groundwater conditions to insure the soil criteria assumed for the design of Line Post Foundations is suitable for the specific site conditions. Conduct the geotechnical investigation in accordance with the ***Soils and Foundations Handbook***, Section 3.2.2.10.

Commentary: Soil and groundwater conditions are very important to the design and performance of a HTCB system. End Terminal Anchorage and Line Post Foundations that are not adequately designed may result in excessive foundation movement during cable tensioning, temperature changes, and/or vehicle impacts. Line Post Foundations shown on the Manufacturer's IPL drawings include "Saturated" and "Unsaturated" *designs. The "Saturated" design is provided for locations near ditches or median bottoms where stormwater runoff may accumulate for short periods following wet weather. End Terminal Anchor Foundations will be designed by the systems manufacturer or Contractors Specialty Engineer in accordance with **Developmental Specifications** Section 540.*

Plan Content Requirements

Insert the entire ***Developmental Design Standards*** Index, received from the Central Office monitor, into the appropriate component plan set in accordance with ***PPM***, Volume 2, Section 3.8. In addition, provide detail in the Plans to cover the following:

1. Typical Sections:

- Lateral Offset - Include the lateral offsets determined during the design evaluation for all segments of HTCB on the Roadway Typical Sections. Additionally, show the alignment of the barrier on the Roadway Plan View.

2. Roadway Plan Views:

- LON - Indicate on the Roadway Plan View the station and offset at all Begin/End Length of Need locations. Include the HTCB Run No. at the Begin/End of each run of barrier. If limited space is available for the End Terminal Assembly, indicate the space available and note that end terminals of lesser length are required.
- Line Post Spacing - Indicate changes in line post spacing requirements along the entire length of each run of HTCB, including the begin and end stationing limits along with the spacing requirement.
- Mow Strip - Provide begin and end stationing for any segments of HTCB for which a specific type of Mow Strip is required (i.e. Concrete or Asphalt).

3. Special Details:

- Overlap - Include Station and Offset for Length of Need locations. If the overlap is intended to provide Maintenance and Emergency Vehicle (Median Crossover) access, special details for grading and/or paving maybe required.
- Median Crossovers - Include locations of Median Crossovers and any special details which may be required to show the geometry of the crossover and location of the HTCB.

4. Geotechnical: Provide Report of Core Borings sheets along with Geotechnical Design Information and indicate when to use "Saturated", "Unsaturated" or "Special Design" (i.e. site specific design) line post foundation designs (See Item 5, Design Data Tables). Include begin and end stationing for any segments of HTCB for which a specific foundation type is required. Identify areas where groundwater is anticipated to be encountered during construction of the foundations.

5. Design Data Tables: Complete the HTCB Design Data Tables (See Example A) using the following instructions and include in the Data Tables on a supplement detail sheet along with Developmental Design Standard Index D450. See Introduction I.3 for more information regarding use of Data Tables. The Data Tables can be downloaded from the ***Developmental Design Standards*** website using the CEL-D450 link.

a. Complete the "Geotechnical Information" tables for both "End Terminal Foundations" and "Line Post Foundations" based on project soil conditions. Columns may be added to include additional Soil Descriptions/Design Values, if needed (no other additions or deletions are permitted).

b. Complete the "Summary of HTCB Locations and Foundations" table based on the project requirements. Include the Begin/End Station for each Line Post Foundation Type and Line Post Spacing, as required by design. Add a soil description for each "Special Design" case included.

c. Include all of the information for a specific run of HTCB on the same sheet.

d. If there are more than four runs of HTCB on a given project, add additional sheets as needed. When more than one sheet of Design Data Tables are needed, include the HTCB Run Numbers in the Sheet Heading (bottom right of sheet).

Payment

Item number	Item Description	Unit Measure
904-540-13	HTCB Length of Need Segment	LF
904-540-14	End Terminal	EA
904-540-15*	End Terminal Foundation (Misc. Drilled Shaft)	CY
904-540-16	Concrete Mow Strip	LF
339-1	Miscellaneous Asphalt Pavement	TN
904-540-13	HTCB Length of Need Segment	LF

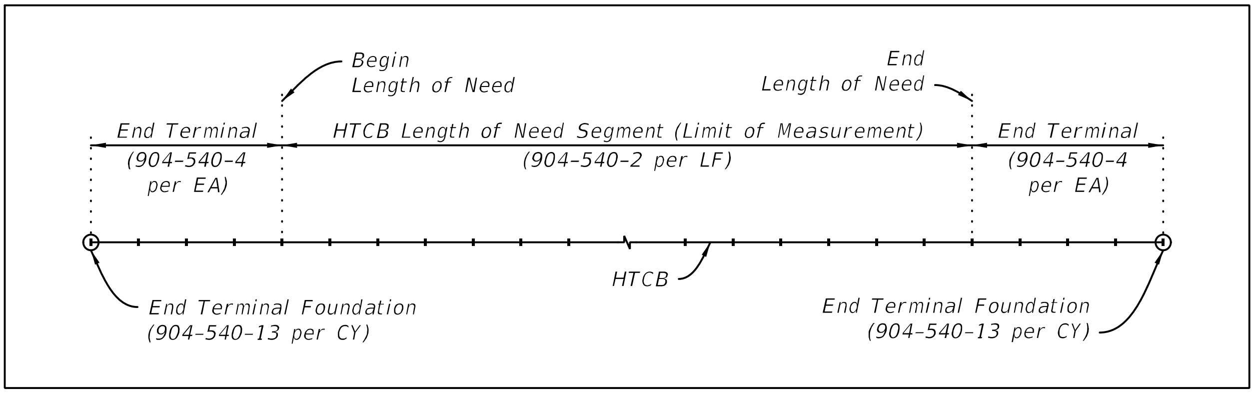
(*) Note: For End Terminal Foundations include 4 CY per End Terminal as the quantity shown in the Plans.

Commentary: HTCB will be paid for as described in ***Developmental Specifications*** *Section 540. The "HTCB Length of Need Segment" (Pay Item 904-540-13) includes the General HTCB segments only, do not include the length of the End Terminal Assemblies (See Figure 6). Payment for End Terminal Foundations (Pay Item 904-540-15 per CY) will be made based on the Shop Drawings submitted and approved during construction. Quantity provided above is for bid purposes only.*

An example of the Pay Item Summary table is included as Example B. To aid in the creation of the summary table, a spreadsheet has been developed to work with the

FDOT Linked Data Manager (FDOT CAD Menu) and can be downloaded from the ***Developmental Design Standards*** *website using the Summary Table link.*

Figure 6 HTCB Method of Measurement



Example A HTCB Data Tables

GEOTECHNICAL INFORMATION – END TERMINAL FOUNDATIONS (Table Date 1/23/15)

		Begin of Run				End of Run			
Soil Description		Loose Fine Sand	Dense Silty Fine Sand		Design Groundwater Depth (ft)	Dense Fine Sand	Loose Clayey Sand	Soft Sandy Clay	Design Groundwater Depth (ft)
Depth Below Existing Ground Line (ft.)	HTCB Run No. 1	0.0 - 10.0	10.0 - 35.0		10.0	0.0 - 20.0		20.0 - 40.0	20.0
	HTCB Run No. 2	0.0 - 15.0	15.0 - 35.0		15.0	0.0 - 5.0	5.0 - 35.0		> 35.0
	HTCB Run No. 3	0.0 - 35.0			5.0		0.0 - 25.0	25.0 - 40.0	20.0
	HTCB Run No. 4								
Total Unit Weight (pcf)		110	115		—	115	112	118	—
Effective Unit Weight (pcf)		48	53		—	53	50	56	—
Cohesion (psf)		0	0		—	0	0	800	—
Internal Friction Angle (deg)		29	31		—	33	29	0	—

SUMMARY OF HTCB LOCATIONS AND FOUNDATIONS (Table Date 1/23/15)

HTCB Run No.	GENERAL HTCB SEGMENTS		Line Post Foundation Type (*)	SPECIAL LINE POST SPACING		
	Begin Station	End Station		Post Spacing (ft)	Begin Station	End Station
1	1523+52	1528+50	1			
	1528+50	1538+00	1	10	1528+50	1538+00
	1538+00	1549+36	SD#1			
2	1604+21	1654+76	2	10	1604+21	1654+76
3	1655+26	1675+00	1	10	1655+26	1670+00
	1675+00	1680+00	SD#2			
	1680+00	1701+06	1			

(*) See "GEOTECHNICAL INFORMATION – LINE POST FOUNDATIONS" Data Table
1 = Unsaturated
2 = Saturated
SD#1 = Special Design (Very Loose Silty Sand)
SD#2 = Special Design (Soft Sandy Clay)

GEOTECHNICAL INFORMATION – LINE POST FOUNDATIONS (Table Date 1/23/15)

	Unsaturated Sand	Saturated Sand	SD#1	SD#2
Design Groundwater Depth (ft)	N/A	0	> 10.0	1.0
Total Unit Weight (pcf)	112	112	100	110
Effective Unit Weight (pcf)	N/A	50	38	48
Cohesion (psf)	0	0	0	500
Internal Friction Angle (deg)	30	30	28	0

NOTE:
SD# corresponds to the Special Design Number shown on the "SUMMARY OF HTCB LOCATIONS AND FOUNDATIONS" Data Table.

NOTES:
1. See Developmental Design Standards Index. No. 450 for General Notes and Details (Sheet _#_).
2. See Shop Drawings for End Terminal and Line Post Foundation Details.

HIGH TENSION CABLE BARRIER (HTCB) DESIGN DATA TABLES
HTCB Run No. 1 through 3

REVISIONS			
DATE	DESCRIPTION	DATE	DESCRIPTION

STATE OF FLORIDA
DEPARTMENT OF TRANSPORTATION

ROAD NO.	COUNTY	FINANCIAL PROJECT ID

SHEET NO.

Example B HTCB Summary of Quantities

SUMMARY OF HIGH TENSION CABLE BARRIER											
LOCATION	SIDE	HTCB LENGTH OF NEED SEGMENT		END TERMINAL		END TERMINAL* FOUNDATION		CONCRETE MOW STRIP		DESIGN NOTES	CONSTRUCTION REMARKS
STA. TO STA.		0904540 13		0904540 14		0904540 15		0904540 16			
		LF		EA		CY		LF			
		P	F	P	F	P	F	P	F		
SUB-TOTAL:											
TOTAL:											

REVISIONS					STATE OF FLORIDA DEPARTMENT OF TRANSPORTATION				SHEET NO.
DATE	DESCRIPTION	DATE	DESCRIPTION		ROAD NO.	COUNTY	FINANCIAL PROJECT ID		