CHAPTER 2 – ROADSIDE AND MEDIAN BARRIER DESIGN AND DETAILS

TABLE OF CONTENTS

2.1—INTRODUCTION

A roadside barrier is a longitudinal barrier used to shield motorists from natural or man-made obstacles located along either side of a traveled way. A median barrier is a longitudinal barrier most commonly used to separate opposing traffic on a divided highway.

Roadside and median barriers are usually categorized as flexible, semi-rigid or rigid depending upon their deflection characteristics resulting from impact. Cable barriers are usually classified as flexible, w-beam guardrail as semi-rigid and concrete/steel bridge barriers or concrete roadway barriers as rigid. Test levels for each of these barrier types are normally Test Level 3 or Test Level 4. Other test levels may be used when appropriate for the site based on specific site conditions and other design performance criteria.

2.2—ROADSIDE BARRIERS

The w- beam strong post guardrail applications are the most common roadside barrier system and are used to protect bridge ends, overhead sign posts, bridge columns, roadway slopes or other obstacles. Concrete safety shape roadside barriers are also used for occasional applications when needed based on the project site needs.

2.2.1—Guardrail Design

The current DOTD MASH Standard Plan uses a generic semi-rigid TL-3, 31” w - beam guard rail height with steel or wood post system, w-beam splices typically at mid-span between posts and a typical 8” wood block out. Guard rail posts mounted through asphalt or concrete pavements shall use specific pavement block out details as shown in the DOTD Standard Plans. The designer must determine the guardrail location, design length, layout details, pay items and quantities for each specific site location design. The layout details and design shall also reference the Standard Plans as needed to be included in the plan set. Design variables include design speed, ADT, lane widths, shoulder widths, site cross slope issues and location of the roadside obstacle.

The latest AASHTO Roadside Design Guide tables and equations shall be used to determine the clear zone, length of need, run out length, shy line offsets, flare rates, horizontal curve adjustments and other required variables. The layout variables are also defined in the DOTD Standard Plans. The designer must also determine whether a flared guardrail design or a tangent guardrail design is used based on the site conditions. For guardrail end treatment systems, refer to the current DOTD Approved Materials List (AML) on the DOTD Materials Section website.

For bridge end applications the guardrail layout design typically consists of a transition section that is attached to a rigid bridge railing, a length of w-beam guardrail based on the length of need and an end treatment section. For non-bridge end applications, a trailing end anchorage section is typically used at the end of the guardrail layout only when a typical crashworthy end treatment is not required. See Chapter 4 for more information on trailing end anchorage sections and guardrail end terminals.

A typical example of a guardrail bridge design criteria and layout table that is required for each site and to be shown in the plan details is shown below.

Guardrail Design Criteria Typical Table

GUARD RAIL DESIGN CRITERIA			
HWY CLASS	DESIGN SPEED (MPH)	DESIGN* ADT	L_C
UA-3	50	34,400	28.0
*20 year future ADT is typical requirement unless noted otherwise			

Guardrail Layout Requirements Typical Table

GUARD RAIL LAYOUT REQUIREMENTS (FT)							
BRIDGE SIDE	L_R	L_A	a/b	L_2	X	Y	Z
Ⓐ	330	28	11:1	20.00	62.50	22.70	32.83
Ⓑ	330	28	11:1	8.00	131.25	16.86	27.00
Ⓒ	330	28	0:0	20.00	100.00	8.00	17.00
Ⓓ	SEE PLAN FOR GUARDRAIL LAYOUT						

Guardrail Layout Variables:

- L_C = required clear zone (ft.)
- L_A = distance from edge of travel lane to the lateral extent of object or the outside edge of the clear zone (L_C) (ft.). $L_A = L_C$ for bridge applications unless otherwise approved by the Bridge Design Administrator
- L_2 = distance from edge of travel lane to tangent section of guardrail (ft.)
- L_R = runoff length (ft.)
- X = calculated length of need (ft.)
- Y = distance from edge of the travel lane to the beginning of the length of need (ft.)
- Z = distance from edge of the travel lane to the edge of embankment (ft.)
- a (horizontal)/b (vertical) = flare rate

The following guardrail design information is included here.

- Guardrail Design Tables 1-4. AASHTO Roadside Design tables for L_C, L_R, shy line offset, flare rates (a/b) and design equations for X, Y and Z.
- Design Information for Guardrail in Curve.
- Example 1 - An example guardrail layout including design requirements for a typical bridge replacement project.
- Example 2 - An example embankment widening roadway detail required for the guardrail layout.

TABLE 1
CLEAR ZONE DISTANCE (Lc)
(IN FEET FROM EDGE OF TRAVELED LANE)

SPEED (MPH)	DESIGN ADT	⊗ FORESLOPE		⊗ BACKSLOPE		
		6H:1V OR FLATTER	5H:1V TO 4H:1V	3H:1V	4H:1V TO 5H:1V	6H:1V OR FLATTER
40 OR LESS	UNDER 750	7 - 10	7 - 10	7 - 10	7 - 10	7 - 10
	750-1500	10 - 12	12 - 14	12 - 14	12 - 14	12 - 14
	1500-6000	12 - 14	14 - 16	14 - 16	14 - 16	14 - 16
	OVER 6000	14 - 16	16 - 18	16 - 18	16 - 18	16 - 18
45 TO 50	UNDER 750	10 - 12	12 - 14	8 - 10	8 - 10	10 - 12
	750-1500	14 - 16	16 - 20	10 - 12	12 - 14	14 - 16
	1500-6000	16 - 18	20 - 26	12 - 14	14 - 16	16 - 18
	OVER 6000	20 - 22	24 - 28	14 - 16	18 - 20	20 - 22
55	UNDER 750	12 - 14	14 - 18	8 - 10	10 - 12	10 - 12
	750-1500	16 - 18	20 - 24	10 - 12	14 - 16	16 - 18
	1500-6000	20 - 22	24 - 30	14 - 16	16 - 18	20 - 22
	OVER 6000	22 - 24	*26 - 32	16 - 18	20 - 22	22 - 24
60	UNDER 750	16 - 18	20 - 24	10 - 12	12 - 14	14 - 16
	750-1500	20 - 24	*26 - 32	12 - 14	16 - 18	20 - 22
	1500-6000	26 - 30	*32 - 40	14 - 18	18 - 22	24 - 26
	OVER 6000	*30 - 32	*36 - 44	20 - 22	24 - 26	26 - 28
65 TO 70	UNDER 750	18 - 20	20 - 26	10 - 12	14 - 16	14 - 16
	750-1500	24 - 26	*28 - 36	12 - 16	18 - 20	20 - 22
	1500-6000	*28 - 32	*34 - 42	16 - 20	22 - 24	26 - 28
	OVER 6000	*30 - 34	*38 - 46	22 - 24	26 - 30	28 - 30

* WHERE A SITES SPECIFIC INVESTIGATION INDICATES A HIGH PROBABILITY OF CONTINUING ACCIDENTS OR SUCH OCCURRENCES ARE INDICATED BY ACCIDENT HISTORY, THE DESIGNER MAY PROVIDE CLEAR ZONE DISTANCES GREATER THAN SHOWN IN TABLE 1. CLEAR ZONES MAY BE LIMITED TO 30 FEET FOR PRACTICALITY AND TO PROVIDE A CONSISTENT ROADWAY TEMPLATE IF PREVIOUS EXPERIENCE WITH SIMILAR PROJECTS OR DESIGNS INDICATES SATISFACTORY PERFORMANCE.

⊗ BACKSLOPE MAY ALSO BE REFERRED TO AS A CUT SLOPE AND FORESLOPE AS A FILL SLOPE.

⊞ FLARE RATES SHOWN FOR BARRIERS INSIDE THE SHY LINE ARE DESIRABLE RATES AND MAY BE WAIVED IF THE GUARD RAIL LENGTH BECOMES TOO LONG FOR A GIVEN SITUATION.

EQUATIONS FOR COMPUTING LENGTH OF NEED (X) AND OFFSETS (Y&Z). (ALL DIMENSIONS ARE IN FEET.)

$$"X" = \frac{L_A + (\frac{b}{a})(L_1) - (L_2)}{(\frac{b}{a}) + (\frac{L_A}{L_R})}$$

$$"Y" = L_A - (\frac{L_A}{L_R})(X)$$

$$"Z" = "Y" + \frac{b}{a}(12.5') + 9'$$

TABLE 2
HORIZONTAL CURVE ADJUSTMENTS
$CZ_c = (L_c)(K_{cz})$

WHERE:
CZ_c = CLEAR ZONE ON OUTSIDE OF CURVATURE, FEET
L_c = CLEAR ZONE ON TANGENT SECTION, FEET (TABLE 1)
K_{cz} = CURVE CORRECTION FACTOR

K_{cz} = CURVE CORRECTION FACTOR

RADIUS (FT)	DESIGN SPEED (MPH)					
	40	45	50	55	65	70
2950	1.1	1.1	1.1	1.2	1.2	1.2
2300	1.1	1.1	1.2	1.2	1.2	1.3
1910	1.1	1.2	1.2	1.2	1.3	1.4
1640	1.1	1.2	1.2	1.3	1.3	1.4
1475	1.2	1.2	1.3	1.3	1.4	1.5
1315	1.2	1.2	1.3	1.3	1.4	
1150	1.2	1.2	1.3	1.4	1.5	
985	1.2	1.3	1.4	1.5	1.5	
820	1.3	1.3	1.4	1.5		
660	1.3	1.4	1.5			
495	1.4	1.5				
330	1.5					

TABLE 3
L_R = RUNOUT LENGTH

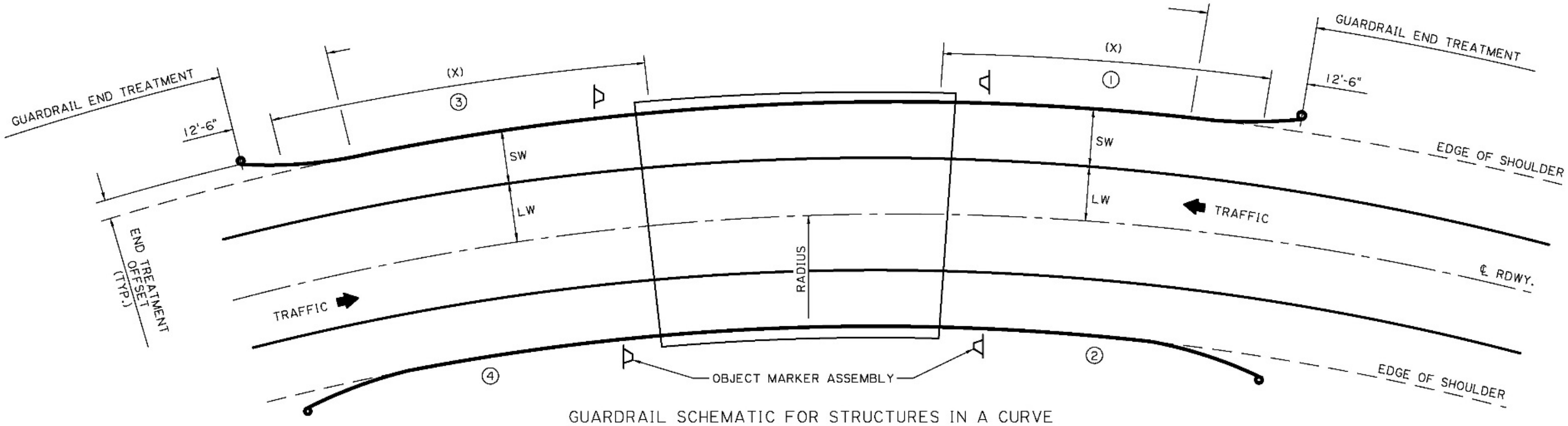
DESIGN SPEED (MPH)	DESIGN TRAFFIC VOLUME (ADT)			
	OVER 10000 VPD	5000-10000 VPD	1000-5000 VPD	UNDER 1000 VPD
	RUNOUT LENGTH L_R (FT.)	RUNOUT LENGTH L_R (FT.)	RUNOUT LENGTH L_R (FT.)	RUNOUT LENGTH L_R (FT.)
70	360	330	290	250
60	300	250	210	200
50	230	190	160	150
40	160	130	110	100
30	110	90	80	70

TABLE 4
SHYLINE OFFSET & FLARE RATES

DESIGN SPEED (MPH)	L_S SHYLINE OFFSET (FT.)	⊞MAXIMUM FLARE RATE (a:b) FOR BARRIER INSIDE SHYLINE	MAXIMUM FLARE RATE (a:b) FOR BARRIER BEYOND SHYLINE	
			⊠RIGID BARRIERS	□SEMI-RIGID BARRIERS
70	9	30:1	20:1	15:1
60	8	26:1	18:1	14:1
55	7	24:1	16:1	12:1
50	6.5	21:1	14:1	11:1
45	6	18:1	12:1	10:1
40	5	16:1	10:1	8:1
30	4	13:1	8:1	7:1

⊠ SUCH AS CONCRETE BARRIER UNITS
□ SUCH AS W BEAM OR THRIE BEAM GUARD RAIL SYSTEMS

GUARDRAIL DESIGN TABLES 1-4



GUARDRAIL SCHEMATIC FOR STRUCTURES IN A CURVE
N.T.S.

FORMULA FOR COMPUTING GUARDRAILS LENGTH OF NEED (X) IN A CURVE

① ② $A = \cos^{-1}\left[\frac{R+LW}{R+LW+CZ_c}\right] - \cos^{-1}\left[\frac{R+LW}{R+LW+SW}\right]$

$X = \frac{A\,(R+LW+SW)}{57.3}$

③ ④ $A = \cos^{-1}\left[\frac{R}{R+CZ_c}\right] - \cos^{-1}\left[\frac{R}{R+LW+SW}\right]$

$X = \frac{A\,(R+LW+SW)}{57.3}$

NOTES:

1. GUARDRAILS COMPUTED IN ACCORDANCE WITH THE ABOVE EQUATIONS SHALL BE INSTALLED PARALLEL WITH THE CURVE OF THE ROADWAY. END TREATMENT SYSTEMS SHALL USE APPLICABLE OFFSETS WHEN REQUIRED.
2. LENGTH OF NEED (X) ON ONE WAY TRAFFIC SHALL USE THE EQUATION SHOWN FOR LOCATION ① & ②. WHEN A BRIDGE IS LOCATED IN A RADIUS > 2680 FT., THE LENGTH OF NEED (X) SHALL BE COMPUTED AS STRAIGHT GUARDRAIL AS PER STANDARD LENGTH OF NEED EQUATIONS AND FLARE RATE.

CZc : ADJUSTED CLEAR ZONE FOR HORIZONTAL CURVE, FT.

R : RADIUS OF CURVE @ ℄ ROADWAY, FT.

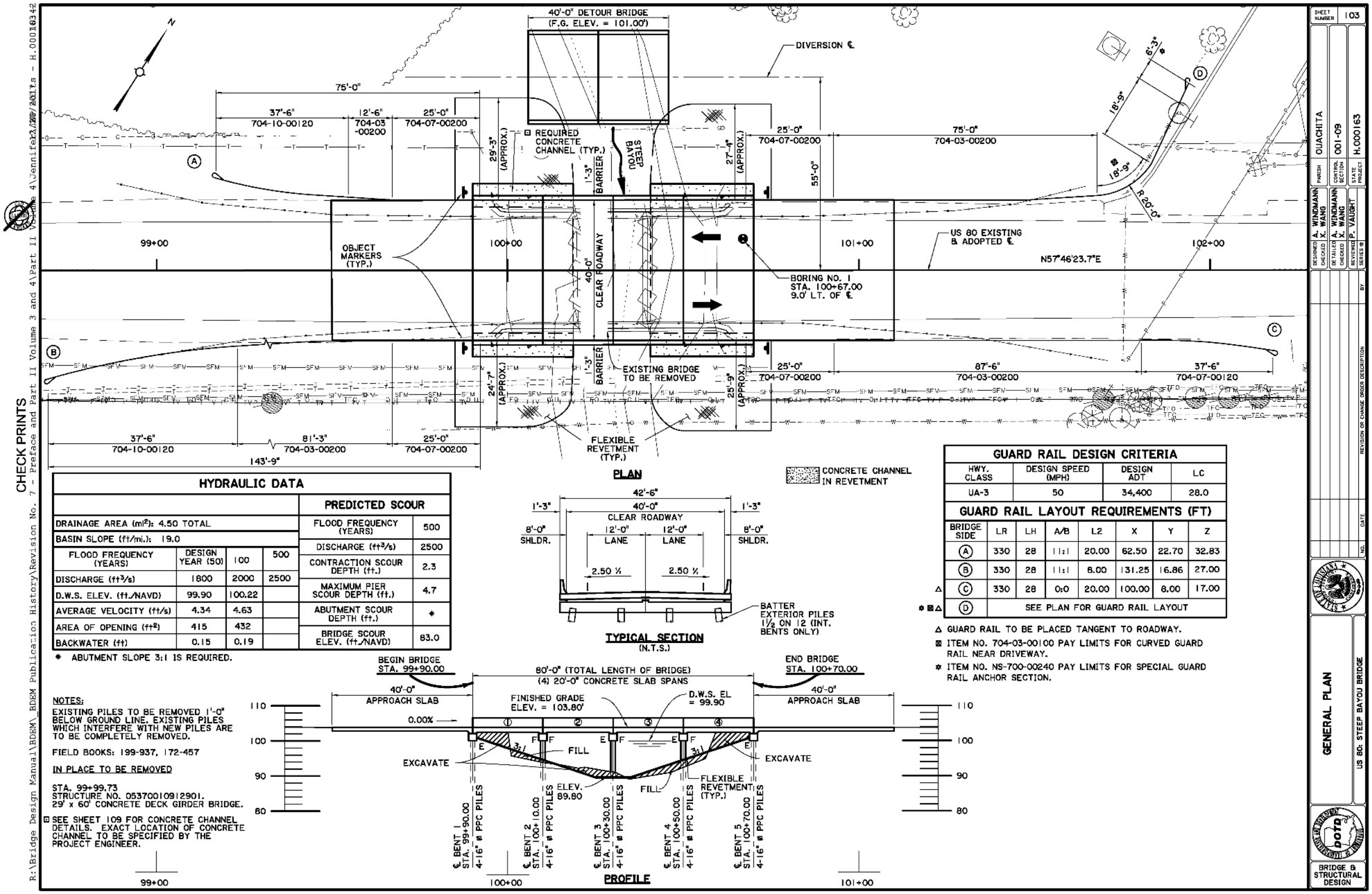
LW : LANE WIDTH, FT.

SW : SHOULDER WIDTH, FT.

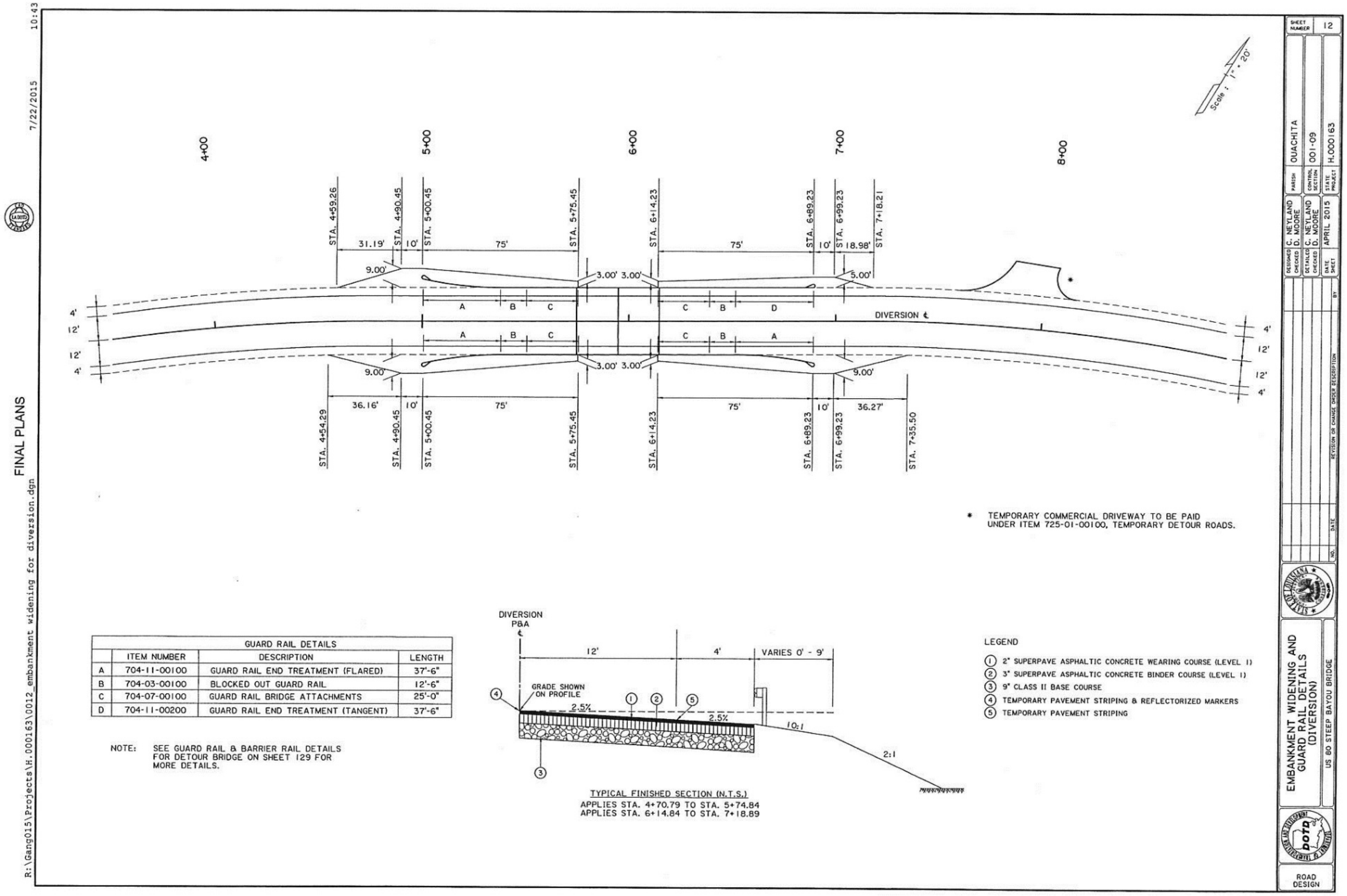
X : LENGTH OF NEED, FT.

A : ANGLE AT CENTER FOR LENGTH OF NEED, DEGREE

DESIGN INFORMATION FOR GUARDRAIL IN CURVE



EXAMPLE 1 – EXAMPLE GUARDRAIL LAYOUT



EXAMPLE 2 – EXAMPLE EMBANKMENT WIDENING FOR GUARDRAIL LAYOUT

For more information, refer to the DOTD guardrail Standard Plans and DOTD EDSM's.

2.2.1.1—Roadway Side Slopes for Bridge Replacement Projects

The purpose of placing guardrail at bridge ends is to prevent vehicles from impacting the end of the bridge rail and to redirect vehicles away from other objects around the bridge.

Many existing roadway slopes have side slopes steeper than 3:1 side slopes. This condition may exist for many miles along a route and it is often impractical to install guardrail along the entire length of these roads for individual bridge replacement projects.

Therefore, on bridge replacement projects located on existing roadways with steeper than 3:1 existing roadway side slopes and where no other significant improvements will be made to the existing roadway, it is acceptable to design the bridge end guardrail assuming a 4:1 slope (the steepest value reported in the AASHTO Roadside Design Guide) and the appropriate ADT.

Furthermore, the new embankment behind the new guardrail on these roadways may be placed at a 3:1 slope or flatter provided that a 10:1 slope or flatter slope exists in front of the guardrail and extends 2 feet behind the guardrail posts as required by the DOTD Standard Plans for Highway Guardrail.

Each bridge replacement site is unique and the design of guardrail and side slopes should be tailored to fit the site with the intent of matching the existing conditions or improving them when possible.

2.2.2—Concrete Barrier

Concrete Safety shape rigid barriers may be used based on deflection needs at the project sites. Typically concrete barriers consist of F-shape or single slope barrier shapes at varying heights. The concrete barrier heights are generally 32” minimum for Test Level 3 (TL-3), 36 inch minimum for test level 4 (TL-4) and 42” minimum for test level 5 (TL-5) for AASHTO MASH applications.

2.3— MEDIAN BARRIER DESIGN

Median barriers are longitudinal barriers most commonly used to separate opposing traffic on a divided highway. Median barriers are typically designed to redirect vehicles impacting from either side of the barrier. Typical median barrier systems are flexible cable barriers, semi-rigid guardrail or rigid concrete rigid safety shapes. The median barrier system to be used typically depends on factors such as deflection criteria, construction cost, test level and other site design requirements.

2.3.1—Cable Barriers

Cable barriers are proprietary flexible longitudinal roadside barriers used to contain and/or redirect errant vehicles that depart the roadway and are typically used in interstate medians. Test levels for cable barrier are typically either test level 3 (TL-3) or test level 4 (TL-4).

Cable barriers consist of high tension steel cables, steel posts mounted to a foundation and an end anchorage foundation system. A gating end terminal is typically used at the end of each cable barrier termination.

The use of cable median barriers recommended on high speed divided highway is based on the following guidelines established by the DOTD Highway Safety Section:

- Median width is greater than 10 feet yet does not exceed 100 feet. For narrow median widths, cable barrier deflection design criteria shall be investigated to determine if cable barrier is an appropriate system;

- No barrier is present in the median with the exception of short overlaps at transitions or where an existing barrier protects a fixed object;
- Full access control of entire corridor is maintained;
- Cable barrier system sits on a concrete strip centered along the cable barrier as depicted in NS concrete strip engineering specification and pay item(s); and
- All hardware and installation adhere to the NS Cable Barrier System engineering specification and pay item(s).

These guidelines are the result of a statewide comprehensive study conducted by the DOTD Highway Safety Section in 2015 based on previously constructed cable median barrier projects. The goal of these guidelines is to identify locations with a potential for reducing fatal and injury crossover crashes.

Cable median barriers may also be considered on high speed divided highways with open or limited access control based on existing safety performance or high potential for crossover crashes. Designers may contact the DOTD Highway Safety Section for access to this information and for technical assistance in determining the existing safety performance and appropriate countermeasures. Exceptions to this guidance shall be documented by the engineer of record.

A cable barrier design must determine its location, length, layout details, pay items and quantities for each specific project site. The layout details and design shall reference the DOTD special provisions. Design variables include design speed, ADT, lane widths, median widths, median slopes, site cross slope issues and location of any roadside obstacles (bridge columns, overhead sign posts, etc.). Geotechnical soil strength and soil classification information is required for each project site for the design of the line posts and end anchorage system. In most cases the foundations for the line posts and end anchorage systems are drilled shaft foundations. Typically cable barrier concrete strips are also used under each cable barrier along the entire length of installation.

Refer to the current DOTD Non-Standard (NS) special provision for cable barrier and cable barrier concrete strips for construction and design information. The specification gives guidance on post spacing, cable barrier placement and allowable median slope requirements. If the site requirements dictate the placement of the cable barrier near the travel lanes, then the post spacing is typically decreased based on the manufacturers recommendations to prevent excessive deflections. Placement of cable barriers closer to a travel lane may also involve more impacts to the barriers and cause higher maintenance costs which should be considered during design. Small gaps or openings in the barriers may be considered for emergency access and should be coordinated with the DOTD District, law enforcement agencies and other emergency officials.

2.3.2—W-Beam Guardrail

Semi-Rigid W-beam guardrail applications may be used for median applications. Consideration should be given to the existing site constraints, deflection requirements and future maintenance when considering this median alternative. Refer to the DOTD Standard Plans for the double sided w-beam 31" median barrier test level 3 (TL-3) detail. Single sided W-beam guardrail applications may also be used in wide median applications to protect sign posts, bridge columns and other obstacles. If project sites involve horizontal curves with super-elevation, the designer shall take into consideration the variance of the roadway elevations on each side of the roadway when designing the double sided w-beam guardrail. Special w-beam guardrail details are typically required for these applications in order to maintain the required guardrail height due to the vertical elevation difference on each side of the divided roadway.

2.3.3—Concrete Barrier

Rigid concrete barriers are typically used when applicable for some high speed divided highways and to limit barrier deflection due to impact. The most common applications are for interstate widening projects that add additional capacity by utilizing part or all of the existing median.

The concrete barrier consists of single slope barrier shapes at varying heights with cast-in-place concrete footings. The concrete barrier heights are generally test level 4 (TL-4) 42 inch or 54 inch height depending on the site location. The barriers are typically supported by a reinforced concrete footing independent of the roadway/shoulder section. Design forces are based on the current AASHTO LRFD Section 13 design forces for traffic railings.

If project sites involve horizontal curves with super-elevation, the designer shall take into consideration the variance of the roadway elevations on each side of the median when designing the double sided concrete barrier. Site specific concrete barrier designs and details are typically required for these applications in order to maintain the required barrier height due to the vertical elevation difference on each side of the divided roadway. If the barrier height increases, the structural design shall be checked for the required design loads.

General guidance for use of either the 42 inch or 54 inch barrier is as follows:

- A 42 inch single slope TL-4 concrete barrier is typically used in rural applications or where interchange locations are separated by more than 1 mile.
- A 54 inch single slope TL-4 concrete barrier is typically used in urban applications or where interchange locations are separated by less than or equal to 1 mile.

2.4—TEMPORARY LONGITUDINAL BARRIER – CONSTRUCTION ZONE

During construction projects, temporary longitudinal barrier are typically used when needed to separate active vehicular lanes from construction work zones. Factors such as traffic volume, operating speed, offset, work zone location and duration of the construction should to be considered when applying this barrier type.

The F-shape temporary concrete test level 3 (TL-3) barrier is typically used on DOTD projects. These are precast concrete free-standing barriers typically in 15 foot segment lengths. For roadway or bridge applications with limited working or deflection space in back of the barrier, pinning the barrier to a concrete pavement or bridge deck should be considered.

Temporary concrete barrier terminations are normally protected by an approved crash tested end treatment when needed based on the placement of the barrier.

Refer to the latest DOTD Standard Plans for Temporary Precast Barrier F-shape and Temporary Precast Barrier Transition.