Buried Concrete Barrier Ends in Washington State

WA-RD 916.1

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BURIED CONCRETE BARRIER ENDS IN WASHINGTON STATE

by

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16. ABSTRACT:

There are over 400 buried concrete barrier ends on Washington state routes. While buried concrete barrier ends are no longer included in standard plans, it is not well understood how vehicles are interacting with these structures. An inventory of buried concrete barrier ends was matched with crash data sourced from the WSDOT Engineering Crash Datamart and the Crash Location & Analysis System (CLAS) database for the years 2011 through 2020 to determine the distribution of crashes in location and severity. During this ten-year period, 36 crashes with these ends were reported and they included only one fatal crash and no serious injury crashes. Most crashes occurred in an urban environment with almost an even split between mainline and exit ramps.

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INTRODUCTION

Buried concrete barrier ends are no longer included in standard plans, except where these ends can be buried in natural backslopes, and there are over 400 remaining statewide. It is unknown how and where vehicles are interacting with these structures, and what the outcome of crashes are. This study combines the inventory of buried concrete barrier ends with crash data to determine if these structures warrant further study or replacement.

SCOPE AND LIMITATIONS OF THE STUDY

This section presents the scope and limitations of the study.

Scope of the Study

There are 437 buried concrete barrier ends identified in the WSDOT roadside safety feature inventory that was collected in 2019 and 2020. This report examines the locations of these structures and the crashes involving these ends.

The buried concrete barrier ends can be divided into three categories which are somewhat subjective:

- Buried (Type A). The concrete barrier end is buried with fill dirt with an otherwise flat surrounding area. See Figure 1.
- Buried in Backslope (Type B). The concrete barrier end is buried in a backslope. There may or may not be fill dirt added to complete the burial. See Figure 2. These types of installations are still allowed if installed in accordance with WSDOT Design Manual 1610.06(3).
- Ambiguous (Type C). The concrete barrier end is buried with somewhat of a backslope, or there is some other reason why it cannot be placed in the other two categories. See Figure 3.

Crashes associated with these concrete barrier ends were identified and analyzed as part of this project.

Limitations

Buried concrete barrier ends are not explicitly identified as a type of object struck in the Crash Datamart. Crashes with *Concrete Barrier* or *Earth Bank or Ledge* as the first or second object struck were extracted that occurred within 500 feet of the buried concrete barrier ends to locate related crashes.

The study did not assess individual buried concrete ends to determine whether the buried end was located within the clear zone or not, and no distinction is made in the dataset between leading and trailing ends.

Figure 1 Buried End (Type A)

Figure 2 Buried in Backslope End (Type B)

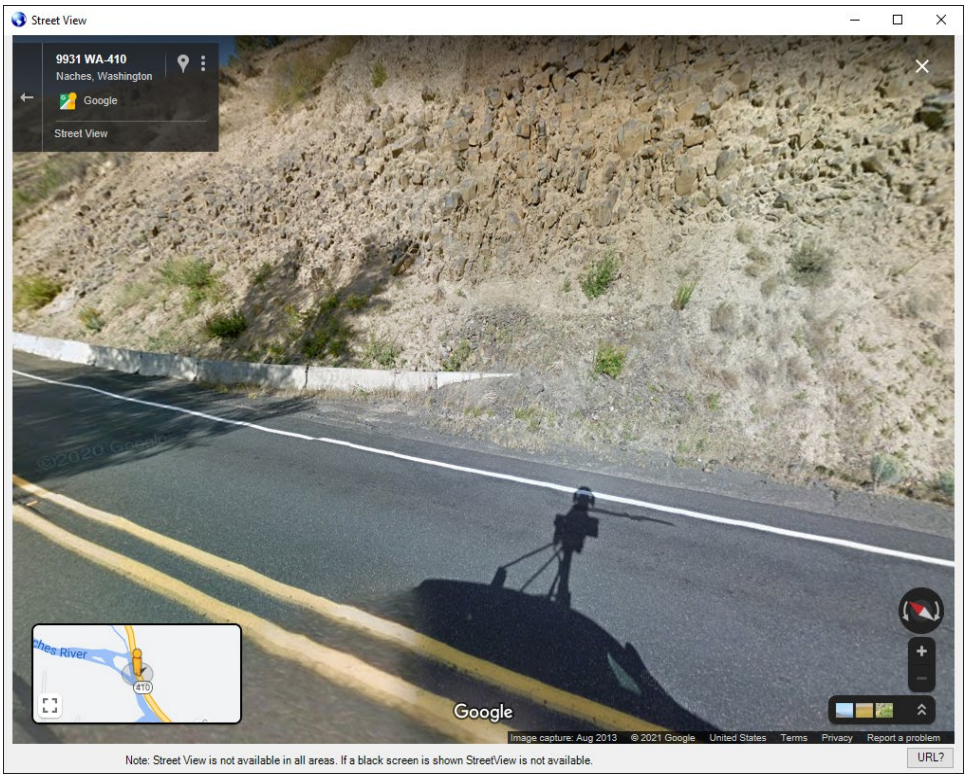

Figure 3 Ambiguous End (Type C)

DATA AND METHODOLOGY

The study used data from the WSDOT Engineering Crash Datamart from 2011-2020 and the most current WSDOT roadside safety feature inventory collected in 2019 and 2020. The inventory was collected using orthography, the WSDOT SR View application, and tools such as Google Street View and Microsoft Birds Eye.

The data used in the analysis combined the crash and inventory location data spatially. First all crashes in the WSDOT Engineering Crash Datamart from 2011-2020 involving *Concrete Barrier* or *Earth Bank or Ledge* located within 500 feet of buried concrete barrier ends were identified: a total of 1,514 crash records. The Police Traffic Collision Reports (PTCRs) were then manually reviewed for each crash to determine if the buried concrete barrier end was involved. A total of 36 crashes involving buried concrete barrier ends were identified. Note that the initial review of five years of crash data, as is recommended practice at WSDOT, rendered such a small sample of crashes that the search was expanded to a ten-year analysis period.

Table 1 through Table 6 present the distribution of buried concrete barrier ends by type and location.

Table 1 shows the count of buried concrete barrier ends by type. The majority is Buried but Buried in Backslope is also well represented, indicating that all types should be included in the study.

Table 1 Buried Concrete Barrier End Type Count

Concrete Buried End Type	Number of features	Percentage of the total
Type A (Buried)	229	52.40%
Type B (Buried in Backslope)	136	31.12%
Type C (Ambiguous)	72	16.48%
Grand Total	437	100.00%

Table 2 shows the count of buried concrete barrier ends by their location on a state route mainline versus a ramp. Type C (Ambiguous) and Type B (Buried) are represented roughly 2:1 on mainlines but Buried in Type B (Buried in Backslope) is over-represented on mainlines.

Table 2 Buried Concrete Barrier End Type Count by Mainline vs. Ramp Location

Concrete Buried End Type	Mainline	Ramp	Total
Type A (Buried)	152	77	229
Type B (Buried in Backslope)	114	22	136
Type C (Ambiguous)	49	23	72
Grand Total	315	122	437

Table 3 shows the count of buried concrete barrier ends by their location on interstate versus non-interstate. Type C (Ambiguous) and Type A (Buried) have a roughly even split but Buried in Backslope is over-represented over 2:1 on non-interstate.

Table 3 Buried Concrete Barrier End Type Count by Interstate vs. Non-Interstate Location

Concrete Buried End Type	Interstate	Non-Interstate	Total
Type A (Buried)	122	107	229
Type B (Buried in Backslope)	39	97	136
Type C (Ambiguous)	34	38	72
Grand Total	195	242	437

Table 4 shows the count of buried concrete barrier ends by speed limit, if known. Most of the features are located on 50+ MPH zones. Note that unknown speed limits are usually associated with ramp locations where no posted speed limits exist.

Table 4 Buried Concrete Barrier End Type Count by Speed Limit

Concrete Buried End Type	Posted speed limit (mph)				
	0-35	40-45	50+	Unknown	Total
Type A (Buried)	2	19	131	77	229
Type B (Buried in Backslope)	6	16	92	22	136
Type C (Ambiguous)	0	4	45	23	72
Grand Total	8	39	268	122	437

Table 5 shows the count of buried concrete barrier ends by functional class. Most of the features are located in urban environments, either urban interstate or urban other freeways/expressways.

Table 5 Buried Concrete Barrier End Type Count by Functional Class

Functional Class	Type A (Buried)	Type B (Buried in Backslope)	Type C (Ambiguous)	Total
Rural Interstate	16	5	4	25
Rural Major Collector	8	26	2	36
Rural Minor Arterial	16	23	5	44
Rural Other Freeways / Expressways	4	6	3	13
Rural Other Principal Arterial	22	19	10	51
Rural Total	**66**	**79**	**24**	**169**
Urban Interstate	106	34	20	170
Urban Major Collector	4	0	0	4
Urban Minor Arterial	1	8	4	13
Urban Other Freeways / Expressways	40	10	12	62
Urban Other Principal Arterial	12	5	2	19
Urban Total	**163**	**57**	**48**	**268**
Grand Total	**229**	**136**	**72**	**437**

Table 6 shows the counts of buried concrete barrier ends by all the previous categories, including crash counts. 34 out of 36 crashes occurred in urban areas, with a majority on urban interstate and 50+ speed limits. Crashes were nearly evenly split between mainlines and ramps. There does not appear to be a concentration of crashes on a particular facility category (functional class, posted speed) or buried end type.

Table 6 Buried Concrete Barrier End Type by Mainline vs. Ramp, Interstate vs. Non-Interstate, Speed Limit, and Functional Class

Facility Type	Posted Speed	Terminal Type	Mainline				Ramps				Features Subtotal	Crashes Sub-total
			Interstate		Non-Interstate		Interstate		Non-Interstate			
			Features	Crashes	Features	Crashes	Features	Crashes	Features	Crashes		
Rural Interstate	50+	Type A	11								**25**	
		Type B	5									
		Type C	2									
		Subtotal	**18**									
	Unknown	Type A					5					
		Type B										
		Type C					2					
		Subtotal					**7**					
Rural Major Collector	0-35	Type A									**36**	
		Type B			1							
		Type C										
		Subtotal			**1**							
	40-45	Type A			3							
		Type B			11							
		Type C			1							
		Subtotal			**15**							
	50+	Type A			5							
		Type B			14							
		Type C			1							
		Subtotal			**20**							

Facility Type	Posted Speed	Terminal Type	Mainline				Ramps				Features Subtotal	Crashes Sub-total
			Interstate		Non-Interstate		Interstate		Non-Interstate			
			Features	Crashes	Features	Crashes	Features	Crashes	Features	Crashes		
Rural Minor Arterial	40-45	Type C			6	1					**44**	**2**
		Type A			4							
		Type B			1							
		Subtotal			**11**	**1**						
	50+	Type A			9							
		Type B			19							
		Type C			4							
		Subtotal			**32**							
	Unknown	Type A							1	1		
		Type B										
		Type C										
		Subtotal							**1**	**1**		
Rural Other Freeways / Express ways	50+	Type A			4						**13**	
		Type B			6							
		Type C			3							
		Subtotal			**13**							
Rural Other Principal Arterial	40-45	Type A									**51**	
		Type B										
		Type C			1							
		Subtotal			**1**							
	50+	Type A			22							
		Type B			19							
		Type C			9							
		Subtotal			**50**							

Facility Type	Posted Speed	Terminal Type	Mainline				Ramps				Features Subtotal	Crashes Sub-total
			Interstate		Non-Interstate		Interstate		Non-Interstate			
			Features	Crashes	Features	Crashes	Features	Crashes	Features	Crashes		
Urban Interstate	50+	Type A	55	13							**170**	**27**
		Type B	20	1								
		Type C	16									
		Subtotal	**91**	**14**								
	Unknown	Type A					51	11				
		Type B					14	2				
		Type C					14					
		Subtotal					**79**	**13**				
Urban Major Collector	50+	Type A			4	1					**4**	**1**
		Type B										
		Type C										
		Subtotal			**4**	**1**						
Urban Minor Arterial	0-35	Type A									**13**	**1**
		Type B			2							
		Type C										
		Subtotal			**2**							
	40-45	Type A			1							
		Type B										
		Type C			1	1						
		Subtotal			**2**	**1**						
	50+	Type A										
		Type B			6							
		Type C			3							
		Subtotal			**9**							

Facility Type	Posted Speed	Terminal Type	Mainline				Ramps				Features Subtotal	Crashes Sub-total
			Interstate		Non-Interstate		Interstate		Non-Interstate			
			Features	Crashes	Features	Crashes	Features	Crashes	Features	Crashes		
Urban Other Freeways / Express ways	40-45	Type A			7						**62**	**4**
		Type B										
		Type C										
		Subtotal			**7**							
	50+	Type A			13	1						
		Type B			2							
		Type C			5							
		Subtotal			**20**	**1**						
	Unknown	Type A					1	1	19	1		
		Type B							8	1		
		Type C							7			
		Subtotal					**1**	**1**	**34**	**2**		
Urban Other Principal Arterial	0-35	Type A			2						**19**	**1**
		Type B			3							
		Type C										
		Subtotal			**5**							
	40-45	Type A			2							
		Type B			1							
		Type C										
		Subtotal			**3**							
	50+	Type A			8	1						
		Type B			1							
		Type C			2							
		Subtotal			**11**	**1**						
Grand Total			**109**	**14**	**206**	**5**	**87**	**14**	**35**	**3**	**437**	**36**

ANALYSIS AND FINDINGS

There was only one fatal crash and no serious injury crashes from 2011 through 2020 (10 years) among the 36 identified crashes with the features (see Table 7). The initial analysis reviewed only five years of crashes but because of the low crash counts during this period, the five-year period was extended to ten years. This increased the sample size somewhat but overall frequency of crashes involving these buried ends remain low.

In the fatal crash the vehicle (a Toyota Camry), departed the roadway to the left, struck the Type B (Buried in Backslope) end, rode up the barrier, slid along the top of the concrete barrier, and then impacted the post of a large overhead sign structure behind the barrier. The driver was over the legal limit for both alcohol and cannabis. There were no other passengers or vehicles involved.

Table 7 shows the total crashes with concrete buried ends by severity. There was only one fatal or serious injury crash involving these features. Simply put, if there were 1000 concrete buried ends, it would equate to a fatal and serious injury crash among all of these ends every 4.4 years, an evident injury crash every 1.1 years, a possible injury every 4 months and a property damage only crash every month.

The question then becomes how the number of crashes with these concrete buried ends can be placed into perspective. To this end, Table 8 summarizes the performance of guardrail end treatments between 2016 and 2020, showing that the performance of these devices is quite similar. The percentage fatal and serious injury crashes with guardrail end treatments are slightly higher at 3.4% compared to the 2.8% of buried concrete ends.

Table 7 Crash Count by Severity for 2011 through 2020 (Source: WSDOT Engineering Crash Datamart)

Crash Severity	Number of crashes with buried concrete ends (10-year total)	Crashes per unit per year	Crash intervals for an equivalent 1000 concrete buried ends	% of total crashes with concrete buried ends
Fatal crashes	1	0.00023	4.4 years	2.8%
Serious injury crashes	0	0	N/A	0%
Evident injury crashes	2	0.00046	2.2 years	5.6%
Possible injury crashes	8	0.00183	6 months	22.2%
Property damage only crashes	25	0.00572	2 months	69.4%
Total	**36**	**0.00824**	**1.5 months**	**100%**

Table 8 Impacts with guardrail end treatments on state highways from 2016 to 2020 (Source: WSDOT Engineering Crash Datamart)

Crash Severity	Crashes with guardrail end treatments	Crashes with guardrail end treatments per unit per year	Crash intervals for an equivalent 1000 guardrail end treatments	% of total crashes with guardrail end treatments
Fatal crashes	17	0.00009	11.7 years	1.9%
Serious injury crashes	14	0.00007	14.3 years	1.5%
Evident injury crashes	84	0.00042	2.4 years	9.2%
Possible injury crashes	143	0.00072	1.4 years	15.6%
Property damage only crashes	657	0.00329	4 months	71.8%
Total	**915**	**0.00458**	**3 months**	**100%**

Table 9 shows crash count by location. As also shown in Table 6, crashes were nearly evenly split between mainlines and ramps with a majority occurring on interstate.

Table 9 Crash Count by Location

Location	Number of Crashes	Number of Features
Interstate	30	196
Mainline	10	109
Ramp	20	87
Non-Interstate	6	241

Mainline	5	206
Ramp	1	35
Grand Total	**36**	**437**

Table 10 shows crash count by type. Impacts with the Type A (Buried) end type represents 86% of the total crashes with buried ends while the Type A end type represents 52% of all the concrete buried end types. The Type B (Buried in Backslope) end type represents 31.1% of the inventory while only 11.1% of the crashes with buried ends occurred at Type B locations.

Table 10 Crash Count by Type

Type	Number of Crashes	Number of Features	% of Crashes	% of Features
Type A (Buried)	31	229	86.1%	52.4%
Type B (Buried in Backslope)	4	136	11.1%	31.1%
Type C (Ambiguous)	1	72	2.8%	16.5%
Grand Total	**36**	**437**	**100%**	**100%**

Figure 4 shows the histogram of AADT, indicating that most crashes occurred in the lower end of the AADT range.

Figure 4 AADT Distribution

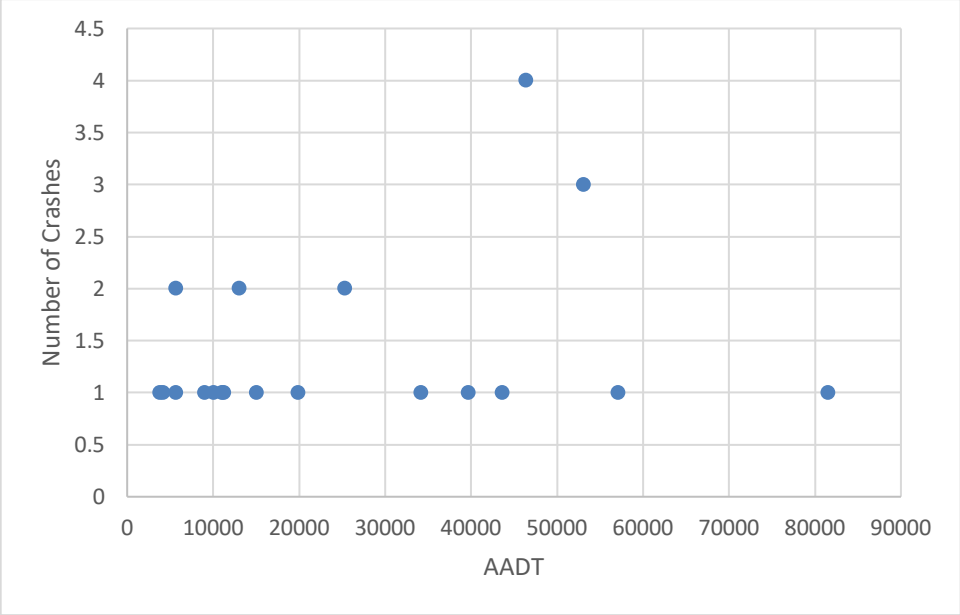

Table 11 shows the AADT by crash severity. There was only one fatal crash and one evident injury crash, so no AADT range is specified. There were no serious (A) crashes.

Table 11 AADT by Crash Severity

Crash Severity	Minimum AADT	Average AADT	Maximum AADT
Fatal crashes	-	81476	-
Serious injury crashes	-	-	-
Evident injury crashes	5661	26020	46379
Possible injury crashes	4179	28535	57050
Property damage only crashes	3737	26163	53049

Table 12 shows the outcomes of the crashes (as determined from the PCTR narrative) by type. The Type A (Buried) type caused the greatest number of rollovers and vaults. A vault is where the vehicle became airborne and lost total control over speed and direction, indicated by the PCTR narrative explicitly using the term “vault”, “air”, or “airborne”.

Table 12 Crash Outcomes by Type

Type	Number of Crashes	Rollovers	Vaults
Type A (Buried)	31	7	5
Type B (Buried in Backslope)	4	1	0
Type C (Ambiguous)	1	1	0
Grand Total	**36**	**9**	**5**

Table 13 shows the total crashes with concrete buried ends that have a rollover post-harmful event by severity. There were no fatal or serious injury crashes involving these features. If there were 1000 concrete buried ends, there would be an evident injury crash every 4.4 years, a possible injury every 2.2 years and a property damage only crash every nine months.

Table 14 summarizes the rollover performance of guardrail end treatments between 2016 and 2020.

Table 13 Rollover Count by Severity for 2011 through 2020 (Source: WSDOT Engineering Crash Datamart)

Crash Severity	Number of rollovers with buried concrete ends (10-year total)	Rollovers per unit per year	Rollover intervals for an equivalent 1000 concrete buried ends	% of total rollover with concrete buried ends
Fatal crashes	0	0	N/A	0%
Serious injury crashes	0	0	N/A	0%
Evident injury crashes	1	0.00023	4.4 years	11.1%
Possible injury crashes	2	0.00046	2.2 years	22.2%
Property damage only crashes	6	0.00137	9 months	66.7%
Total	**9**	**0.00206**	**6 months**	**100%**

Table 14 Rollovers with guardrail end treatments on state highways from 2016 to 2020 (Source: WSDOT Engineering Crash Datamart)

Crash Severity	Rollovers with guardrail end treatments	Rollovers with guardrail end treatments per unit per year	Rollover intervals for an equivalent 1000 guardrail end treatments	% of total rollovers with guardrail end treatments
Fatal crashes	8	0.00004	25 years	8.2%
Serious injury crashes	4	0.00002	50 years	4.1%
Evident injury crashes	17	0.00009	12 years	17.5%
Possible injury crashes	24	0.00012	8 years	24.7%
Property damage only crashes	44	0.00022	4.5 years	45.4%
Total	**97**	**0.00049**	**2 years**	**100%**

Table 15 shows the total crashes with concrete buried ends that have a vault post-harmful event by severity. There were no fatal or serious injury crashes involving these features. If there were 1000 concrete buried ends, there would be an evident injury crash every 4.4 years, a possible injury crash every 2.2 years and a property damage only crash every 2.2 years.

Table 16 summarizes the vault performance of guardrail end treatments between 2016 and 2020. This data was obtained by searching the PTCR narratives for the same keywords used to identify vaults for the buried concrete barrier ends ("vault", "airborne", and "air") and manually reviewing the reports.

Table 15 Vault Count by Severity for 2011 through 2020 (Source: WSDOT Engineering Crash Datamart)

Crash Severity	**Number of vaults with buried concrete ends (10-year total)**	**Vaults per unit per year**	**Vault intervals for an equivalent 1000 concrete buried ends**	**% of total vault with concrete buried ends**
Fatal crashes	0	0	N/A	0%
Serious injury crashes	0	0	N/A	0%
Evident injury crashes	1	0.00023	4.4 years	20%
Possible injury crashes	2	0.00046	2.2 years	40%
Property damage only crashes	2	0.00046	2.2 years	40%
Total	**5**	**0.00114**	**10 months**	**100%**

Table 16 Vaults with guardrail end treatments on state highways from 2016 to 2020 (Source: WSDOT Engineering Crash Datamart)

Crash Severity	**Vaults with guardrail end treatments**	**Vaults with guardrail end treatments per unit per year**	**Vaults intervals for an equivalent 1000 guardrail end treatments**	**% of total Vaults with guardrail end treatments**
Fatal crashes	3	0.00002	66 years	75%
Serious injury crashes	1	0.00001	200 years	25%
Evident injury crashes	0	0	N/A	0%
Possible injury crashes	0	0	N/A	0%
Property damage only crashes	0	0	N/A	0%
Total	**4**	**0.00002**	**50 years**	**100%**

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In the ten-year period from 2011 through 2020, 36 crashes on WSDOT state highways under WSDOT jurisdiction involved impacts with buried concrete ends. The current inventory indicates that there are 437 buried concrete barrier ends on the state highway network.

86% of the crashes with buried concrete ends was with the Type A (Buried) end type. These devices represent 52% of buried concrete ends on the system. It is frequently found on urban interstates and urban interstate ramps. It is also associated with the highest number of vaults and rollovers: 7 and 5 respectively.

In 11% of the crashes with buried concrete ends, a Type B (Buried in Backslope) type was hit. This end type represents 31% of buried concrete ends on the system. These devices are mostly found in rural environments.

The Type C (Ambiguous) end type is least common buried type, representing 17% of these buried ends, and only one crash was reported with this type in the ten years under review (3% of the total crashes). These buried end types are most commonly found in rural environments.

The performance of the buried ends is better than the performance of other end treatments with respect to fatal and serious crashes:

- The overall percentage of fatal and serious injury crashes with buried ends is 2.8% compared to 3.4% of other guardrail end treatments.
- The percentage of fatal and serious injury crashes with rollovers as a post-harmful event is 0% compared to 12.3% of other guardrail end treatments. Rollovers are more common for buried concrete barrier ends for all crash severities. When considering hypothetically 1000 units of buried concrete barrier ends and 1000 units of end treatments, the equivalent rollover event would occur once every six

months at buried concrete barrier ends compared to once every two years for a group of 1000 guardrail end treatments.

- The percentage of fatal and serious injury crashes with vaults as a post-harmful event is 0% compared to 100% of other guardrail end treatments. Vaults are more common for buried concrete barrier ends for all crash severities: when considering 1000 buried ends and 1000 end treatments, these vault events would occur once every ten months at one of the 1000 buried ends compared to once every 50 years for the group of 1000 guardrail end treatments. Therefore these events are rare.

Recommendation

Based on the analysis that found a low frequency of crashes involving these features, a low crash severity associated with these crashes, and that their performance with respect to fatal and serious crashes is better than other end treatments, it is concluded that a special I2 subcategory to modify or remove Type A and Type C buried ends is not warranted: the costs will outweigh the return on investment.

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