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PRELIMINARY STUDY ON SNOWPLOW SURVIVABILITY OF GUARDRAIL TERMINALS

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16. Abstract

Based on this preliminary study, the following conclusions are made: (1) Anecdotal evidence indicates that the newly installed SRT-350s are not very forgiving (because they are designed to be crash-friendly), and relatively minor contact between the snow removal equipment and the terminal may result in terminal failure and at least some damage. (2) There are two types of damage to the newly installed SRT-350s: (a) damage due to contact between the snow removal equipment and the terminal; and (b) damage resulting from the pressure of the snow (snow-only contact). The first type is the most likely damage observed in field visits. The damage due to snow-only contact can occur in heavy snow area. (3) Except in heavy snow area, the average replacement rate for newly installed SRT-350s can be reduced to about the same level as the traditional BCTs if the snowplow operators learn to respect the new terminals more and provide them with a wide berth. To achieve this, it is very important to mark the end of the terminal as well as the beginning of the flare of the terminal. With both locations marked, an operator can carefully avoid the entire length of the terminal. (4) Further research is needed to investigate guardrail end terminals which are more durable or are easily repaired.

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ABSTRACT

FHWA has asked Alaska Department of Transportation and Public Facilities (DOT&PF) to fix damaged longitudinal and end sections of guardrail throughout Alaska's road system. The proposed research evaluates W-beam guardrail end terminals (GET) which are installed along roads in heavy-snow areas of Alaska. Primarily, it is important for DOT&PF to determine how well GET withstand loads generated during snow plowing and blowing operations. Based on this preliminary study, the following conclusions are made: (1) Anecdotal evidence indicates that the newly installed SRT-350s are not very forgiving (because they are designed to be crash-friendly), and relatively minor contact between the snow removal equipment and the terminal may result in terminal failure and at least some damage. (2) There are two types of damage to the newly installed SRT-350s: (a) damage due to contact between the snow removal equipment and the terminal; and (b) damage resulting from the pressure of the snow (snow-only contact). The first type is the most likely damage observed in field visits. The damage due to snow-only contact can occur in heavy snow area. (3) Except in heavy snow area, the average replacement rate for newly installed SRT-350s can be reduced to about the same level as the traditional BCTs if the snowplow operators learn to respect the new terminals more and provide them with a wide berth. To achieve this, it is very important to mark the end of the terminal as well as the beginning of the flare of the terminal. With both locations marked, an operator can carefully avoid the entire length of the terminal. (4) Further research is needed to investigate guardrail end terminals which are more durable or are easily repaired.

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Introduction

The W-beam guardrail has traditionally been the first choice for use in protecting the motoring public from serious roadside hazards. This wide usage results from its favorable safety record, ease of construction and repair, and low cost. One trouble spot for this system has been the difficulty in safely treating the end of the barrier. As a result, since the 1960s, research in guardrails has been focused on guardrail end treatment. Tests indicated that the standard terminal section (27 ½ in. long) was extremely dangerous [1]. A collision with an untreated guardrail will have severe results for vehicle and its occupants. The most satisfactory solution found in the 1960s was to slope the guardrail into the ground and anchor it in concrete. The length of the sloped-end treatment was varied with speeds driven at these sites. Posts were 6 ft 3 in. on centers (about 37 ft long). This end treatment had the advantage of using standard materials which all guardrail contractors could supply. However, the solution to ramp the end sections down to the ground, which allowed the car to slide upward, was later found to be too steep. The car could be pitched violently up in the air when the car was driving about 60 mph [2].

To avoid the problem associated with the sloped-end terminal, the Breakaway Cable Terminal (BCT) was later developed [3]. BCT is a gating end treatment designed to allow controlled barrier penetration for vehicles impacting on its end. The gating action is provided by breakage of a wood post and dynamic buckling of a flared guardrail section. Longitudinal anchorage for the guardrail is provided by a cable attached to the leading wood post in such a way that, when the post breaks, the cable is released. This system was originally designed to accommodate full-size automobiles and was shown to perform well for both head-on and side impacts. Based on these early successful crash tests, many states adopted the BCT as a standard guardrail terminal. Because the BCT relies on dynamic buckling of a flared section of W-beam, it is very sensitive to the way the barrier end is flared. More, recent crash tests have indicated that standard BCT designs will not perform satisfactorily when impacted by

mini-size vehicles. An improved BCT design, the Eccentric Loader BCT (ELT) [4] was later developed and successfully crash tested with mini-size vehicles. Although this system should offer improved safety performance over the standard BCT, the flared barrier end remains a critical component of the design.

An important milestone in the development of the terminals is the FHWA rule that requires all safety devices installed on federal-aid highways after September 1998 meet the new NCHRP Report 350 standards [5]. Even though a great effort was directed toward improving the BCT and ELT to meet NCHRP requirements, none of these systems have passed NCHRP Report 350 requirements. To meet the new NCHRP 350 standards, several new terminals have developed, including the slotted rail terminal (SRT) [6], the ET-2000 [7], the beam-eating steel terminal (BEST) [8], the sequential kinking terminal (SKT) [9], and the flared W-beam guardrail terminal (FLEAT) [10]. It is very important to point out that all of these new terminals have been developed based on ultimate crash-loading cases. Normal service loading, such as loads caused by actual snow plowing and blowing operations, has not been considered. As a result, the SRT-350s have not held up well – many reportedly damaged as snow was pushed against them by snowplows in Alaska. Half of the SRT-350s recently installed in Turnagain Pass in Alaska were damaged after a single winter.

FHWA has asked Alaska Department of Transportation and Public Facilities (DOT&PF) to fix damaged longitudinal and end sections of guardrail throughout Alaska's road system. A pilot study has been carried out to evaluate W-beam guardrail end terminals (GET) which are installed along roads in heavy-snow areas of Alaska. The primary objective of this study is to focus on GET problems and possible solutions to them through survey, interview, as well as field investigation. The results of this study are summarized here.

FIELD INVESTIGATION

Damage to SRT-350s

With the objective of identifying the types and severity of damage to the newly installed guardrail terminals, the research team first visited Anchorage region Maintenance and Operations. In the Anchorage area, Bill Mowl, Superintendent of Anchorage District Maintenance and Operations, Jerry Reed, Anchorage Maintenance Foreman, and Larry Anderson, Silver Tip Maintenance Foreman, were interviewed. The research team then went to Valdez. In the Valdez area, Bill Lusk, Valdez Foreman, and Mark Walker, Thompson Pass Foreman, were interviewed.

The Anchorage maintenance crews find the new slotted rail terminals (SRT-350s) fragile. The research team confirmed this statement through field visits. As an example, Fig. 1 shows the damage to the slotted area in the W-beam of SRT-350s. This type of damage could be caused by direct contact from the snowplow equipment or by snow-only contact, i.e. too much snow had been pushed against the slotted W-beam through snow removal operations parallel to the rail. The research team could not identify the exact cause of this damage. However, by comparing the slotted portion of the W-beam with the portion away from the slots shown in Fig. 1, it can be observed that the slotted portion has a lower bending resistance during snowplow operations.

Fig. 1 Damage to the Slotted Area in W-beam of SRT-350s

Although the maintenance crews did not know whether the damage shown in Fig. 1 was caused by the snow-only contact, they have observed significant damage due to routine winter maintenance in the Turnagain Pass region. In Valdez area, very heavy snow falls can be expected with at least 300 inches in the lower elevations and as much as 600 to 800 inches in Thompson Pass. The snow tends to be wet and heavy variety. Difting is a significant concern in many locations. The maintenance crews already attempt to operate three to four feet away from the terminal, but they are still observing damage to the new terminals.

Another chief concern to these maintenance crews is the use of wooden posts for the terminal treatment that tend to shear away from its steel-tube base. It is important to point out that holes at the base of wooden posts (as shown in Fig. 2), similar in function to slots in the W-beam, intend to soften the new terminals during a vehicle collision. However, it does make them more fragile during the normal snowplow operations. After a post shears off its base, as shown in Fig. 3, the replacement effort is prohibitive because the base must be dug out of the ground.

Fig. 2 Wooden Posts with Holes

Fig. 3 Wooden Post Broke away from Its Steel-Tube Base

Additionally, the maintenance crews in Valdez area struggle with drainage at and around the guardrail and terminals. Poor drainage can allow sheets of ice to form during freeze-thaw cycles. These maintenance crews believe that they have to replace on average half of the new terminals after every winter season.

The new terminals are extremely expensive at $3000 and require considerable effort to replace. The new terminals require a total of four man-days (2 maintenance workers and 2 flagmen) to complete the replacement.

Snow Removal Strategy

Another objective of this research is to determine if a change in snow removal strategy can minimize damage to the new terminals. The winter maintenance techniques in the state follow a basic pattern. First, trucks are used while the snow is falling and immediately following the storm. This occurs because they move faster than the other equipment. In general, this operation seems to pose little danger to the terminals. Between storm events, the maintenance crews attempt to thoroughly clean the road surfaces using graders. This initial grader action seems to be the action that may precipitate a terminal failure. According to the maintenance operators, the graders will force the snow in large quantities directly into the guardrail end terminal. When a grader gets too close to the terminal, this action may cause the terminal to fail. Additionally, this and the next two maintenance operations tend to place the terminal in peril because the maintenance crews are attempting to clear the entire paved surface. The final two maintenance operations occur in tandem as a grader uses its sloper attachment (as shown in Fig. 4) to pull down the snow berm in the shoulder area caused by the previous operations. Subsequently, a rotary plow or snow blower (as shown in Fig. 5) follows behind and blows the snow well off the traveled surface.

Fig. 4 A Grader with a Sloper Attachment

Fig. 5 A Typical Snow Blower

Recent guardrail terminal replacement projects in Turnagain Pass have installed the new SRT-350 terminals. These new terminals have been present for two winters. During the first winter, the maintenance crews used their typical plowing strategy and cleared the area next to the terminal. Following the winter of 1998-99, half of the brand new terminals were damaged sufficiently to require replacement. After adjusting snow clearance strategy to avoid the area around the terminal during the following winter, only one of the twelve terminals was damaged sufficiently to require replacement. These sites were already repaired; therefore, there existed insufficient evidence to ascertain the cause or causes of these failures. These replacement and damage rates seem much higher than the older type of terminal ends.

Similarly in Valdez area, the maintenance personnel also emphasize the vulnerability of the terminal when the grader operates in its vicinity. Specifically, the sloper attachment tends to catch on the posts and destroy the terminal.

Visibility

The new terminals in Turnagain Pass have been installed at the lower elevations, which only receives about a third (or approximately 130 in.) of the seasonal snowfall that is observed at the pass's peak. This region does not experience a large amount of drifting snow, but the heavy, wet snows seem to pose a special concern with regard to the terminal vulnerability. At this time, the terminal and guardrail ends in this section are marked with six-foot flexi-flags on spring steel, as shown in Fig. 6. This seems to be very effective and allows the operators to find these points throughout the winter. Additionally, the spring steel seems resistant to damage from winter maintenance activities.

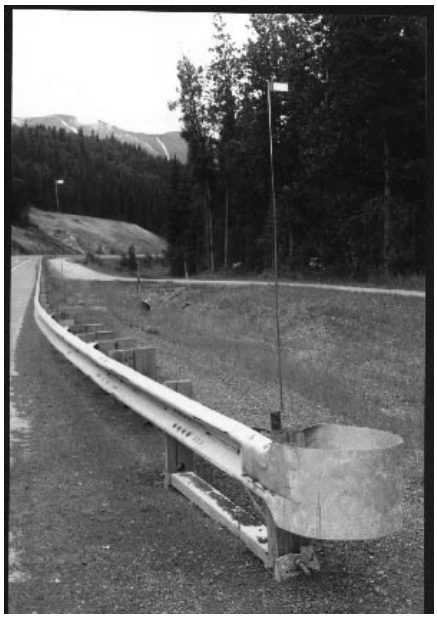

Fig. 6 Six-foot flexi-flags Marker on spring steel

However, in Valdez area, only the terminal ends are marked with an eight-foot carsonite marker, as shown in Fig. 7. While the Valdez area crews are not sold on this marker, they believe it is the best they have found.

Fig. 7 The Eight-foot Carsonite Marker

SURVEY RESULTS FROM NORTHERN-TIER STATES

As part of this investigation, other states that can experience large snowfalls were polled to determine if they are experiencing snow plow damage to the new end terminals. Appendix A shows the questionnaire the research team sent to all states through email. The investigation received responses from the following states: Colorado, Delaware, Idaho, Illinois, Maine, Michigan, Minnesota, Montana, New Hampshire, North Dakota, Oregon, South Dakota, Utah, Vermont, Washington, Wisconsin and Wyoming. None of these states identified terminal failures due to snow-only contact except the heavy snow area in the State of Washington, where snowfall averages anywhere from a season average of 350 inches to over 700 inches and a single event can be three to four feet. The States of Minnesota and Maine identified difficulties with equipment contact with the terminals. Many of these states expressed great interest in the danger of snow-only terminal failure; however, the slow proliferation of the new terminals and the recent mild winters in many of these states make any definitive statement on the existence of snow-only failures throughout the United States impossible.

Effective marking seems to be an effective technique for reducing equipment collisions with the terminals. The strategies for marking the terminals vary somewhat from state to state; however most states use plow markers or fiberglass poles with reflectivity. Another popular marker is simply an extended steel delineator post. Almost all of the agencies only mark the terminal ends. The State of Wyoming emphasizes the use of raised delineators to divide traffic as well as mark the edge of pavement. The State of Minnesota would like to educate their operators in an effort to reduce terminal damage. They would like to use a video that makes operators aware of the damage that they can cause and the costs associated with its repair.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on this preliminary study, the following conclusions are made:

1. Anecdotal evidence indicates that the newly installed SRT-350s are not very forgiving (because they are designed to be crash-friendly), and relatively minor contact between the snow removal equipment and the terminal may result in terminal failure and at least some damage.
2. There are two types of damage to the newly installed SRT-350s: (1) damage due to contact between the snow removal equipment and the terminal; and (2) damage resulting from the pressure of the snow (snow-only contact). The first type is the most likely damage observed in field visits. The damage due to snow-only contact can occur in heavy snow area.
3. Except in heavy snow area, the average replacement rate for newly installed SRT-350s can be reduced to about the same level as the traditional BCTs if the snowplow operators learn to respect the new terminals more and provide them with a wide berth. To achieve this, it is very important to mark the end of the terminal as well as the beginning of the flare of the terminal. With both locations marked, an operator can carefully avoid the entire length of the terminal.
4. Further research is needed to investigate guardrail end terminals which are more durable or are easily repaired.

Recommendations

1. Regardless whether snow-only damage can occur, damage that results from equipment collisions with the terminals seems more likely. The equipment operators need to increase their diligence in avoiding the terminals. The State of Minnesota recommendation for a video that emphasizes the damage and its cost may assist in this

endeavor. Improved training may allow operators to avoid a learning curve where they destroy half of the new terminals during the first winter season. This effort may quickly pay for itself by reducing first-year replacement rates.

2. If Alaska DOT remains concerned that a problem may exist, then they need to implement a photo survey next spring. After the spring thaw, all of the maintenance crews should photograph the damaged terminals in their section. A research strategy can be developed to insure that the maintenance crews capture the proper images. Careful examination of all of these images may be able to identify the total number of terminals damaged by snow removal equipment and the total damaged by snow-only. This effort would enable the Alaska DOT to identify the likelihood of various types of terminal damage and failure.
3. Future research on snowplow survivability of guardrail terminals in heavy snow area should be carried out. The objective of that research should quantify the maximum amount of snowfall, beyond which the snow-only contact could cause damage to the terminals. With this research result, the Alaska DOT can specify acceptance criteria of guardrail terminals in heavy snow area.
4. The maintenance crews in the Valdez area strongly support the investigation of both box-beam guardrails and the use of metal posts in the terminal as opposed to wooden posts. A careful research project may be designed to identify the ease of maintenance and likelihood of damage or failure associated with each post-type.

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Appendix A Questionnaire for Terminal Response to Snowplow Operations

1. Did your agency install either SRT-350 or ET-2000 guardrail terminals before last winter? (if yes, please continue; if no, thank you for your participation)

With respect to snowfall and snow removal operations, please answer the following questions:

2. What is the average replacement rate for new terminals damaged by snow removal?

2a. Is this higher than the older style end terminals?

3. Have you noticed any of the new terminals requiring replacement due to snow-only contact (i.e. the terminal fails because too much snow has been pushed against the terminal through snow removal operations parallel to the rail)?

3a. If so, how many are damaged and how many are installed overall?

4. How are the terminals and guardrails marked?

4a. Is this effective?

5. Do you notice a difference in terminal damage depending on the type and size of the snowfall (i.e. wet vs. dry; drifting vs. non-drifting)?

6. What is the approximate seasonal and/or single-event quantity of snowfall for a given area or roadway segment experiencing trouble with new terminal replacement rates?

7. What is your typical snow removal/management strategy (i.e. what techniques and equipment are used)?

8. What steps have you considered and/or implemented to minimize damage to the new terminals?