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CABLE GUARDRAIL

William (Skip) Outcalt

Interim Report
June 2004

COLORADO DEPARTMENT OF TRANSPORTATION
RESEARCH BRANCH

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This study is monitoring the performance of cable guardrail installed in Colorado. The three-year study will gather accident, maintenance, and repair data from sites and build databases to evaluate the data. Severity of damage to the system when it is hit, including costs and time needed to make repairs will be recorded. Information from accident reports will be included to determine the extent of damage to the impacting vehicles and information on injuries to drivers and passengers.

Current installations include**:** US-285 mp 241 right shoulder EB; US-285 mp 253 right shoulder WB; I-25 mp 250 median, SH-65 mp 32 – 44 both shoulders. Planned installations: I-25 mp 229 to mp 269, median, C-470 mp 20 to mp 24 median.

Implementation:
Data from existing sites can help determine appropriate applications for the use of the system. Experience has shown that cable guardrail is not suitable under certain circumstances.

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EXECUTIVE SUMMARY

In areas with a snow drifting problem, guardrails can act like snow fences and cause snow to drift across the highway. Cable guardrail systems that greatly reduce the problem have been used extensively in Scandinavia, Australia, and New Zealand with considerable success. Tensioned cable guardrail, which recently received NCHRP 350 approval and has NCHRP 350 certified end treatments, could be very useful in Colorado. Deflection, when the guardrail is struck by a vehicle, is limited. The systems are bidirectional, making them useful in narrow areas, both on shoulders and in highway medians. Maintenance is very simple, fast, and inexpensive.

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BACKGROUND

Most of the barrier systems CDOT uses to protect errant vehicles from various hazards along the highway involve either a wide steel rail or a concrete barrier. While they are very effective at containing vehicles, their aesthetics are less than outstanding and, under certain conditions they function as a snow fence, causing hazardous drifts across the highway. Tensioned cable guardrail offers a new possibility that mitigates both of these problems. The relatively narrow posts and the wire rope cables don't provide enough resistance to the wind to act as a snow fence. The narrow profile is less obtrusive visually, and the posts can be powder coated to a brown shade that helps the system blend with the landscape even better. Another benefit of cable guardrail systems is their ability to control errant vehicles with a barrier that has some "give" to reduce the severity of impact when a vehicle does leave the roadway and hit the barrier.

In April of 2001 the Brifen Wire Rope Safety Fence (WRSF), a tensioned 4-cable guardrail system, received NCHRP 350 certification for use on US highways. The system had been in use for several years in Europe, Australia and New Zealand, and had established a reputation for effectiveness and easy, low-cost maintenance and repair. In 2003, Brifen USA, an Oklahoma corporation, obtained rights to produce and market the system in the United States.

In the fall of 2002, CDOT installed Brifen WRSF cable guardrail on US-285 west of Denver at a place called Windy Point. The highway at that location had just been widened to a divided four-lane configuration with a speed limit of 50 MPH. Traffic northbound on US-285 is descending rapidly around a right-hand curve and immediately into a left-hand curve. Off the right shoulder is a high, steep slope that claimed two lives in separate accidents in the previous two years. In an area known for wind, CDOT engineers believed the cable guardrail would not act as a snow fence and its small profile area would not interfere with the picturesque view down the valley the way W-beam guardrail would. It would be a good location for CDOT to evaluate cost and performance of the new guardrail.

Two WRSF systems, one 1100 feet long and the other 1200 feet long, were installed at Windy Point. There is a local access road that intersects US-285 between the two systems.

Installation was completed late in September, 2002 and a study panel was organized to evaluate the function and costs of maintenance and repair of the system. Originally planned as a quick study to evaluate the Windy Point site, the study was expanded to an experimental feature study

due to wide interest and desire to install systems in various locations throughout Colorado. The study panel members felt that taking additional sites into the study as they became available would increase the validity of the study by providing performance information from a variety of different site and traffic conditions. Additionally, as new designs pass NCHRP 350 testing and are certified by the FHWA, they will be included in the study. The plan is for evaluations and data collection to end in June 2005 and for the final report to be written by December, 2005.

SITE DESCRIPTIONS

Table 1. Installed systems as of December, 2003.

(Length figures for median systems do not match mile post locations because they do not include the length of W-beam systems that are used at structures.)

Highway	Length	Terminal Protection	Rail position	Location
US-285 mp 241 s	1200	out of clear zone	Rt. shldr NB	Windy Point
US-285 mp 241 n	1100	out of clear zone	Rt. shldr NB	"
US-285 mp 254		out of clear zone	Rt. shldr SB	Kipling Pkwy
I-25 mp 250 n	2700	both behind W-beam	Median	Berthoud Interchange
I-25 mp 250 s	1550	both behind W-beam	Median	"
SH-65 mp 32.5	1262		Rt. shldr SB	Grand Mesa
SH-65 mp 33.6	1000		Rt. shldr SB	"
SH-65 mp 34	686		Rt. shldr SB	"
SH-65 mp 43.8	697		Rt. shldr SB	"
SH-65 mp 44.1 sb	785		Rt. shldr SB	"
SH-65 mp 44.1 nb	1035		Rt. shldr NB	"

Note: All of the systems listed in the table above were installed before the Brifen NCHRP 350 certified terminal was available, so the terminals are either outside the clear zone or are protected in some way.

Windy Point

The first location, as mentioned above, is on US-285 west of mp 241 on the right shoulder to northbound (downhill) traffic. Two systems are installed at Windy Point; there is an access road between them. Both systems have their post sockets set in concrete, and use terminals that were not 350 certified so they are set outside the clear zone. (At the time of construction in late September of 2002, there were no 350 certified terminals available for cable guardrail systems.)

Kipling Parkway

The second location installed is also on US-285. This system was installed early in 2003 on a straight, flat section of highway east of the mountains at mp 254. This 2400 foot section is at the edge of the right shoulder southbound in an area where a vehicle that leaves the highway would have to travel only a short distance to wind up in the back yard of one of a row of a single-family homes. The upstream end of this system is protected by a section of W-beam guardrail and the downstream end is flared out of the clear zone at the beginning of the exit ramp to Kipling Parkway.

Berthoud Interchange

In the summer of 2003 the third location was installed – two systems in the median of I-25 north and south of the SH-56 overpass at mp 250. Southbound I-25 north of the interchange is going down hill with a right curve followed by a left curve under SH-56 and another right curve to bring the highway back to due south alignment. There have been several accidents at this location caused by icy conditions on the curves and hills and the ramps to and from SH-56.

Grand Mesa

The fourth location is two groups of three systems each, separated by about ten miles. It was built on SH-65 in the west central part of the state during September of 2003. SH-65 is a narrow, winding, two-lane, designated Scenic Byway that connects I-70 east of Grand Junction on the north, over Grand Mesa to SH-92 and US-50 at Delta on the south.

I-25 Brighton to Ft. Collins

Tensioned cable guardrail systems are bidirectional, meaning that they can take hits from either side and contain a vehicle. This capacity means they work well for median applications. Plans are in the final stages that will add nearly 47 miles of cable guardrail to the state inventory in just two projects during 2004 and 2005. The larger of the two is I-25 north of Denver. The plan calls for 40 miles of Brifen WRSF in the median from SH-7 at mp 229 to SH-14 at mp 269, and about 3 miles of Trinity CASS (Cable Safety System) between the mainline and the heavily travelled frontage road from mp 259 to mp 262. The median barrier on this project will have to deal with several conditions not yet encountered in this study, such as differences in elevation between the

northbound and southbound lanes, and crossings over structures and emergency vehicle access through the median.

C-470 Broadway to Quebec

The 47 miles mentioned above includes approximately four miles of cable guardrail that will be installed from Quebec to Broadway in the median of C-470 west of the I-25 interchange during the summer of 2004. This four mile stretch will have to deal with many of the same situations encountered in the I-25 project mentioned above.

SYSTEMS EVALUATIONS

This study will evaluate cable guardrail systems mainly for three criteria:

- Performance in controlling and reducing vehicle damage and injuries in an accident.
- Costs for parts and labor, and length of time between the accident and the repair.
- Availability of repair parts to keep the systems working properly.

Because there are multiple systems installed at most locations, data will be kept by the individual system. For this study a system will include all cable and posts between two end terminals or anchors, and the terminal or anchors themselves.

ACCIDENT HISTORY

The main objective of this study is to evaluate the performance of cable guardrail systems in accidents. Accident records will be kept in an effort to determine how well the systems work to protect vehicles from hazards, to control the final resting point of vehicles that have hit the systems and to reduce the severity of injuries and damage incurred in accidents that involve the cable systems.

Accident data has proved to be difficult to obtain during the first year and a half of evaluations There is a significant time lag after the occurrence of an accident before the Law Enforcement report becomes available. Additionally, many of the accidents are so minor that the vehicle is driven away and law enforcement is not notified. For these reasons and because of the wide distribution of the cable guardrail systems across the state, it is necessary to rely on the CDOT

Maintenance patrols at the locations for information about when systems are hit, how well they perform, and the repair time and costs.

US-285 Windy Point: During the first five months after the installation of the Windy Point site on US-285, Research was notified of four hits. Three of them were so minor that the impacting vehicles left without law enforcement being informed. One required replacement of 4 posts; the second, 2 posts; and the third, 3 posts. The fourth hit was more severe. It involved a CDOT engineer from Durango who credits the Brifen WRSF system with saving his life. This more severe accident required replacement of only 6 posts. None of the accidents required replacement or repair to anything other than posts and hardware such as cable locator pegs and post caps.

Figure 1. The most severe hit on the Windy Point systems damaged only six posts.

Figure 2. Only four posts were bent in this drive-away accident on US-285 at Kipling.

Research has been informed of only one minor hit (damaged just two posts) on the system since February of 2003. Whether this is indicative of a lack of accidents or a lack of communication between Maintenance and Research is unknown.

US-285 at Kipling Parkway: In early May of 2003, the system on southbound US-285 (**Figure 2**) was hit once requiring replacement of 4 posts. This appears to have been another drive-away situation; there is no record of a report to law enforcement, and there have been no reports of any additional hits on the system.

I-25 at SH-56: There have been several hits on the two systems in the median of I-25 at the SH-56 interchange since their installation in August of 2003. Four Colorado State Patrol Traffic Accident Reports concerning these two systems have been received by Research.

Figure 3. The I-25 – SH-56 interchange, looking south.

Three of the accidents occurred on the same day, November 22, 2003, in a period of about an hour, when the area was experiencing icy driving conditions. Two of the accidents were on the system north of SH-56 and one was to the south, beyond the overpass in **Figure 3**.

The two hits on the north section provide some very important information about the Brifen WRSF cable system at this location: These two accidents occurred within just a few minutes of each other – the officer's reports (the same officer responded to both accidents) list the times as 0925 and 0930. The exact location of the accidents is not recorded finely enough to determine what distance there was between the points of impact on the cable systems; however, both reports list the point of impact as 0.1 miles north of SH-56.

While the speeds of the two vehicles at the time of the accidents is not known, since the highway was icy, it is probable that they were travelling slower than the 75 MPH posted speed limit. The cable system contained both vehicles and prevented possible cross-overs that could have resulted in much more serious accidents. There were no injuries to any of the three people involved; one of the vehicles was damaged at the front end and was towed from the scene, the other apparently was driven away.

The fact that the cable guardrail did not collapse as a result of the first crash, thereby letting the second vehicle cross the median into oncoming traffic, is significant. An un-tensioned cable system in the same location probably would have collapsed after the first impact, possibly allowing the second vehicle to cross the median into northbound traffic.

Figure 4. The cables over this drain inlet are much farther off the ground than the design specification.

The fourth accident report, dated February 11, 2004 also provides important information, but of a very different type: A 1995 Honda Accord, northbound on I-25, struck the w-beam guardrail on the right shoulder about 1/4 mile north of SH-56. It then crossed both northbound lanes and the median, went through the cable guardrail without damaging any posts or the cable, and was hit by a southbound vehicle before it continued off the highway to the west.

According to the accident report, in addition to the side hit by the southbound vehicle, the Honda was damaged quite extensively on its top. It appears that the vehicle happened to penetrate the cable system at a drain inlet. The depression at the inlet appears to have allowed the vehicle to pass under the cables. The fact that, according to the accident report, there was considerable damage to the top of the vehicle, and that it did not roll, supports this theory. The accident report specifically mentions that there was no damage to the cables or support posts at the point of penetration.

Figure 4 shows the height of the cables at the drain inlet where it is believed the Honda went under the cable guardrail. About eight inches above the bottom of the post in the foreground there is a flange that is designed to keep debris out of the post socket – that flange should be at ground level. The tension of the woven cables is actually holding the post up partially out of the socket. On the near side of the post the cable can be seen below the locator peg. Normally the lowest cable should be 20 inches above the ground. Because of the depression around the inlet drain in the picture it is considerably higher – enough higher that the Honda mentioned above was able to pass under the entire system. A solution for this problem is discussed in the Recommendations section of this report.

SH-65: There have been no accidents reported to the Research Branch as of June, 2004; however, extensive replacement of posts damaged either directly or indirectly by snowplows will be necessary when the snow has melted.

MAINTENANCE ISSUES

Tensioned cable guardrail is new to CDOT so there are still several questions to be answered concerning maintenance and repair of the systems. Of the eleven systems currently installed in Colorado, all are Brifen WRSF and, as of June 2004, they all are maintained and repaired by CDOT Maintenance personnel.

The time required to make the repairs is very important because it is a safety issue for maintenance personnel working close to the highway. In most cases replacement of the damaged four to six posts has taken under two hours. As Maintenance personnel become more familiar with repair methods, the amount of time needed to replace posts and re-set the cables on the locator pegs should go down.

Spare parts availability is critical to the maintenance of the systems and will be closely observed and recorded – it is a very good indicator of the performance of the systems and of the number of accidents experienced in a given area. Experience both in Colorado and in other states that have tensioned cable guardrail systems indicates that replacement of cable sections will rarely be necessary so they will probably not need to be maintained in stock. However, to maintain the systems in their designed configurations, it will be necessary for the responsible patrol to keep a stock of replacement posts and hardware – locator pegs and post caps - the things that are damaged in an accident.

CONCERNS – PROS AND CONS

Since the beginning of the study in 2002, several different cable guardrail systems have received NCHRP Report 350 test certification as suitable for use along the highway. End terminals that have received NCHRP 350 certification (unavailable in the fall of 2002) have become available for most of these systems, Some of the 350 certified systems use highly tensioned cables. Depending on manufacturer there are both three-cable and four-cable designs. Most of the tensioned systems retain functionality after being hit, as demonstrated by the hits on the I-25 system mentioned above. There are also 350 certified systems that use non-tensioned or low-

tensioned cables that require repair after an accident in order to function as a barrier again. The following table lists some cable barrier manufacturers and some of the characteristics of their systems.

Table 2. Cable guardrail manufacturers

Item	Brifen WRSF	Trinity CASS	Trinity CASS	Trinity CASS	SC 3-Cable	Safence 350 4RI	W-Beam
# of Cables	4	3	3	3	3	4	---
Post Spacing *(may be spaced less)	10'6" * (3.2m)	6'-6" (2m)	9'-10" (3m)	16'-5" (5m)	16'-0" curves R≥700'	8'-2" * (2.5m)	varies
Deflection test 3-11 Note 1	7'-10" (2.4m)	6'-9" (2.06m)	7'-11" (2.4m)	9'-2" (2.8m)	?	8'-10" (2.7m)	~ 3 ft.
Cable Diameter (strands)	¾" (3x7)	¾" (3x7)	¾"(3x7)	¾"(3x7)	¾"	19 mm	---
Tensioned to lb-ft (Note 2)	2,500 – 8,100	3,500 - 7,300	3,500 - 7,300	3,500 - 7,300	none	1,800 - 7,000	---
Functional after hit?	yes	yes	yes	yes	no	yes?	varies
Maximum Slope for non-shoulder placement	≤ 6:1	≤ 6:1	≤ 6:1	≤ 6:1	≤ 6:1	≤ 6:1??	≤10:1
Installation segment lengths	See installed systems	250' to 10,000'	250' to 10,000'	250' to 10,000'	Up to 2000'	Up to 36,000'	---
Approved Terminal Note 1	Yes (gating)	Yes (gating)	Yes (gating)	Yes (gating)	? (gating)	No	Yes
Median width min.	Dependent on post spacing				≥ 24 ft.	Dependent on post spacing	
Project data:							
Cost per ft	$12 - $15 Note 3				$11		$11.44
Typical hit damage	5 Posts						
--typ. repair time	1 Hr						
--typ. cost	<$300				$1000		

Note 1 – NCHRP 350 TL-3 (3/4 Ton truck)
Note 2 – Cable tension is set according to manufacturer specifications depending on the ambient temperature at the time of tensioning.
Note 3 – Installed Costs for CDOT test projects.

Assuming similar system performance, cost is the primary determining factor as to what guardrail system will be selected for installation in a given location. One of the things that makes cable guardrail attractive is the fact that it is less expensive to install and maintain than

other types of guardrail in most situations . As Table 1 above shows, the installation cost of various types of cable rail varies significantly from tensioned cable to non-tensioned systems with the tensioned systems being significantly more expensive in some cases.

Installation costs alone may be misleading, however. In some locations the ability of a system to withstand multiple hits without loss of function may be more important. For an area with a high accident rate, a system with higher installation costs may be less expensive in the long run if it is able to retain its functionality through multiple hits without repair.

A system that retains its effectiveness after being hit allows maintenance personnel and resources to be devoted to time-critical things like snow removal during snow storms, with the knowledge that public safety is not being compromised by waiting to repair the barrier after the storm has passed. It also allows Maintenance personnel to work in relatively safer conditions.

Locations need to be evaluated carefully and individually to determine if cable guardrail systems are the best way to protect a hazard. An area where snow will stand over long periods in the winter and the guardrail must be positioned very near the edge of the pavement is an example of a place where the use of a cable system may be inappropriate - plowing operations tend to damage cable guardrail systems located very close to the highway (see **Figure 5**). Sections of highways where avalanches repeatedly run over the roadway would be another example of a place where a cable system will probably not be satisfactory. It is difficult, if not impossible, for loaders and other heavy equipment to remove the very tightly packed snow in an avalanche runout without damaging a cable guardrail that is buried there.

Figure 5. Posts on SH-65 are bent in all directions, suggesting that the damage is not all caused by snowplows.

The systems that CDOT Region 3 has on SH-65 over Grand Mesa are an example of where snow builds from early in the winter and continues to collect all during the snow season. During the first week of April 2004, the area received 22 inches of

snow. Accumulations of several feet hide the cable system from plow operators, making their jobs more difficult. Some posts are undoubtedly bent by plows. In addition, the weight of the accumulation of snow pushes against the posts, bending others. Many of the posts on SH-65 will need replacement when the snow melts. **Figure 5** shows that the damage to the system is not entirely from plow blades hitting the posts. The fact that some are curved rather than bent over at the base, and some are bent toward the highway suggest that the force of the snow and ice thrown by the plow blades and the weight of the snowbank behind the cables contribute significantly to the damage.

To reduce damage to the cable systems during the winter, it has been suggested that the posts and cables be removed from areas like those described above. Liability issues are one reason that would not be feasible. Maintenance personnel cannot tell when the snow will collect to the point where it will fill in around the guardrail. If they wait too long, they cannot get the system out to storage; if they pull the guardrail too soon they risk leaving a hazard unprotected and incurring a liability situation if there is an accident at that location.

Another wintertime problem is posts freezing into their sockets. This problem has not been reported by CDOT maintenance personnel, but it could present a problem in areas where temperatures are such that water can get into the pockets and freeze to lock the posts in. Brifen USA suggests using a small amount of expanding foam in the top part of the sockets to seal them from water intrusion as one way to prevent having posts frozen into their sockets.

EVALUATION AND RECOMMENDATIONS

Performance

Except for one instance of a vehicle penetrating the system in the median on I-25, all of the cable guardrail in Colorado has performed very well to date. However, cable guardrail may not be the "universal specific" – the best solution for all situations. There are situations where cable guardrail, while perfectly suitable from an accident standpoint, is not suitable for other reasons.

Site Selection

The installations on SH-65 over Grand Mesa are an example of a place where cable guardrail may not be the best solution. Some of the locations where the WRSF was installed along SH-65 are areas where deep snow accumulates and stands through the winter covering the guardrail. The problem is not that the cable guardrail is not functional in the situation; it is that it is difficult

for snowplow operators to clear the highway up to the guardrail without damaging it and that the weight of the standing snow behind the guardrail may actually bend the posts as it settles.

Installation and Maintenance

The height of the cables above the ground is very important to the proper function of the cable guardrail system. It needs to be carefully maintained during the initial installation of the system and must be monitored during maintenance that is performed on the system, particularly following an accident.

From a design and construction standpoint, correct cable height along outside shoulders is usually easy to establish due to the constant slope of the shoulders. Correct cable height can be more easily established in median installations by running the cable guardrail system a set distance from the shoulder line of one side of the highway, rather than down the center of the median. (Brifen USA recommends 18 feet offset from the shoulder stripe if the median is wide enough, which should accommodate mowing operations.) By putting the cable in an area where the slope does not vary up and down in short distances, it is easier to maintain a uniform height for the cables above the surface thus preventing high or low areas where the barrier can be more easily under- or over-driven. A barrier that follows the smooth curves of the highway is also more aesthetically pleasing than one in the center of the median that has to wander from side to side to avoid passing directly over depressions at drain inlets.

It is important to maintain the cables at the correct heights set by the locating pegs on the sides of the posts. In areas where heavy snow is thrown over and through the cable system by snowplows, the impact of the snow and ice on the cables and posts may be strong enough to break or pop out the locator pegs, allowing the cables to sag below the design height. It may be necessary to replace the pegs and reposition the cables to the proper height periodically. **Figure 6** shows cables that are lower on the post than the design heights. The three black pegs sitting on the cable in the picture had been broken from their mounting holes and were lying on the ground near the post. In the picture, a black dot can be seen on the side of the post just below the top cable. It is the hole for the upper cable locating peg for this side of the post. This is where the top pair of woven cables should be, with the lowest cable 6-1/2 farther down the post (about where the woven pair are in the picture).

It is very important that the cable height both sides of the impact point be checked whenever accident damage is being repaired. Movement of the cables during impact often causes the locater pegs to break or pop out of their holes for some distance from the point of impact, even on posts that have not been bent. Cables that are too low or too high are better than no barrier at all. However, as the penetration of the median system on I-25 demonstrates, their effectiveness is reduced.

Figure 6. Cables positioned lower than design height.