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High Tension Cable Median Barrier: A Scanning Tour Report

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<tr><td colspan="4">16. Abstract
The Illinois Department of Transportation (DOT) coordinated a scanning tour to identify effective and efficient approaches of reducing the number and severity of freeway median crossover crashes. Representatives from Illinois, Iowa, Minnesota, and Wisconsin DOTs, and the University of Illinois, visited Ohio, Oklahoma, and Texas to learn from their experiences in the use of high-tension cable barriers, and to gather information on system characteristics and performance from the states and two manufacturers of high-tension cable barrier systems. Field-installed high-tension cable barrier systems from four manufacturers were observed: U.S. High Tension Cable System, Brifen WRSF, CASS, and Safence. These cable barrier systems seem to perform similarly when hit by passenger vehicles. The performance at redirecting or stopping vehicles was reported to be excellent, and no major drawback of using high-tension cable barrier systems was found. It was reported that crash severity was reduced significantly compared to other barrier systems and no fatalities had been recorded on crashes at locations with high-tension cable barriers. Some issues pertaining to optimum cable location, long-term benefit-cost analysis, TL-3 versus TL-4 requirements, 3-cable versus 4-cable systems, and others need additional exploration and experience to be addressed more precisely.</td></tr>
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This scanning tour report was prepared by the Traffic Operations Laboratory (TOL) at the University of Illinois at Urbana-Champaign. The Federal Highway Administration (FHWA), under its Accelerating Safety Activities Program (ASAP) and the Illinois Department of Transportation funded the Scanning Tour and preparation of this report. The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not reflect the official views or policies of IDOT or FHWA. This report does not constitute a standard, specification, or regulation.

Executive summary

The States of Illinois, Iowa, Minnesota, and Wisconsin are interested in installing and/or expanding the use of high-tension cable barriers for cross median protection on their highway systems.

These states took part in a scanning tour with the following objectives: 1) to learn from other states that already have experience in the use of high-tension cable barriers, and 2) to gather information on system characteristics and performance from the states visited and companies that manufacture high-tension cable barrier systems.

The Scanning Tour was founded by the Federal Highway Administration (FHWA) and took place from August 29, 2005 to September 2, 2005. The Tour included visits to Ohio, Oklahoma, and Texas DOTs and some of the cable systems manufacturing companies in those states.

Four proprietary high-tension cable barrier systems were observed: U.S. High Tension Cable System, Brifen WRSF, CASS, and Safence. These systems meet NCHRP 350 criteria for test level 3 (TL-3)[1], which is the main required standard in the visited states. The cable systems use ¾-inch diameter 3 x 7 strand cable ropes (may or may not be pre-stretched depending on the system) and weak posts to guide the cables through and maintain cable height.

The observed cable barrier systems seem to perform similarly when hit by passenger vehicles. The performance at redirecting or stopping vehicles was reported to be excellent, and no major drawback of using high-tension cable barrier systems was found.

It was reported that crash severity was reduced significantly compared to other barrier systems, no fatalities had been recorded on crashes at locations with high-tension cable barriers, and very few crashes had resulted in barrier penetration.

The selection of high-tension cable systems is based on a bidding process, but bidding specifications are not the same among the states though they all require a specific maximum dynamic deflection. Warrants for installation of median cable barrier generally depend on crash history, and are also dependent on roadway geometry and traffic volumes.

High-tension cable barriers may be installed on the shoulder or median, and are recommended for slopes no steeper than 6:1. The states visited preferred socketed posts over driven posts even though the former had a higher installation cost due to embedding the sockets in concrete foundations. The high initial cost seems to balance out over time mainly because post replacement is easier.

[1] The Brifen system has also been accepted at TL-4

The information gathered in this Scanning Tour provided valuable knowledge on the system characteristics, performance, and maintenance, although the states visited are still going through the learning process. Some issues including optimum cable location, long-term benefit-cost analysis, TL-3 versus TL-4 requirements, and 3-cable versus 4-cable systems, and others, need more exploration and experience to be determined precisely.

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Introduction

Illinois, Iowa, Minnesota, and Wisconsin, are interested in installing and/or expanding the use of high-tension cable barriers for cross median protection on their highway systems. Both the Division and National FHWA representatives supported the idea of a scanning tour and helped to secure funding for it. Representatives from these four states participated in a scanning tour of sites in Ohio, Oklahoma, and Texas from August 29, 2005 to September 2, 2005. The purposes of the Scanning Tour were:

- To learn from other states who already have experience in the use of high-tension cable barriers, and
- To obtain information on system characteristics and performance from the visited states and companies that manufacture high-tension cable barrier systems.

A severe crash may occur when a vehicle crosses the median and hits an opposing vehicle. Median barriers are installed to prevent cross median crashes. Median barriers may not reduce the frequency of crashes due to lane departure, but they can prevent the cross median head-on crashes. Also, collisions with rigid barriers, such as concrete, may result in severe injury, either from the collision itself or from a secondary collision if the vehicle is reflected back into traffic.

Median barrier systems using high-tension cable are currently used in many states across the U.S. They are designed not only to reduce the number of cross median crashes, but also crash severity. Cable barriers can deflect more than other type of barriers such as W-beam barriers to reduce the severity of the impact. Cable barriers are also more adaptable to variations in the terrain profile and slopes compared to beamguard barriers, may withstand a second hit before repairs, usually require less grading and drainage work, and to some people they may be aesthetically more pleasing than other barrier systems. However, there are still questions about their performance, cost, installation, and maintenance that need to be answered.

Participants

The following participants came from the Illinois, Minnesota, Iowa, and Wisconsin Departments of Transportation and the University of Illinois:

Name, Position	Agency
David Piper, Safety Design Engineer	Illinois DOT
Deanna Maifield, Methods Engineer	Iowa DOT
Chris Poole, Office of Design	Iowa DOT
Gary Dirlam, District Traffic Engineer	Minnesota DOT
John Hanzalik, Metro Highway Maintenance Supervisor	Minnesota DOT
John Bridwell, Standards Development Engineer	Wisconsin DOT
Peter Amakobe, Standards Development Engineer	Wisconsin DOT
Juan Medina, Graduate Research Assistant	University of Illinois

The University of Illinois was responsible for preparing this report.

Agenda

The agenda included meetings and field visits with DOT representatives, and visits to cable systems manufacturing companies. The following is a summary of the main activities during the Scanning Tour:

Ohio (August 29th – 30th, 2005)

- *Meeting at Ohio DOT and field visit:*
  Visited site: I-270 and Tuttle Crossing Blvd - U.S. High Tension Cable System[2]
  Contact person: Dean Focke, PE Roadway Standards Engineer Ohio DOT.

- *Visit to NUCOR Marion Steel Inc. plant:*
  Contact person: Rich Mauer, National Sales Manager, Marion Steel Company

Oklahoma (August 30th – September 1st, 2005)

- *Meeting at Oklahoma DOT and field visit:*
  Visited sites: - State Highway 75 – Hefner Parkway (Brifen)
  - I-35 (Brifen)
  Contact person: Faria Emamian, P.E. Engineer Manager, Oklahoma DOT

- *Visit to Brifen USA:*
  Contact person: Jerry Emerson, P.E. Marketing Engineer Brifen USA

Texas (September 1st – 2nd, 2005)

- *Meeting at Texas DOT (Weatherford Area Office) and field visit:*
  Visited site: I-20 (CASS – Brifen)
  Contact person: Jimmey Bodiford, P.E. Area Engineer

The complete list of participants in each of the meetings can be found in Appendix 1.

[2] Rainy weather did not permit any close inspection of the installed U.S. High Tension Cable System

Brief Introduction to High Tension Cable Barrier Systems

Four different proprietary high tension cable barrier systems were observed in the Scanning Tour and will be discussed in this report: U.S. High Tension Cable System, Brifen WRSF, CASS, and Safence. The four systems meet NCHRP 350 criteria for test level 3 (TL-3). A modified version of Brifen WRSF also meets the requirements for test level 4 (TL-4). These cable systems use ¾-inch diameter 3 x 7 strand cable ropes (pre-stretched or not pre-stretched depending on the system) and weak posts to guide the cables and maintain cable height.

The basic characteristics of the four systems are briefly described in this section. More information can be found in the manufacturers' product literature and in the NCHRP test conditions and results published by FHWA.

A summary of the systems characteristics and their performance in NCHRP 350 test type 3-11 is presented in Table 1. The table only includes information from official acceptance letters issued by the FHWA to the manufacturers that have been posted on the FHWA official website as of October 2005. This website is continuously updated and it can be visited to obtain the latest information on system designs and variations.

http://safety.fhwa.dot.gov/roadway_dept/road_hardware/longbarriers.htm

System	U.S. High Tension Cable System	Brifen WRSF	CASS	SAFENCE
Manufacturer	NUCOR Marion Steel Inc.	Brifen USA	Trinity Industries Inc.	Blue Systems AB
# of Cables	3	4	3	4
Cable Diameter	19mm diameter (3x7 strands/cable)			
Cable tensioning	Non-prestretched / Prestretched	Prestretched	Prestretched	Prestretched
TL-3 Post Shape	U-channel (Rib-Bak)	S-shape	C-channel	I-post or C-post
Cable Height Above the Ground	750mm, 650mm, 545mm	720mm, 675mm, 510mm (Height #1) or 720mm, 600mm, 460mm (Height #2)	750mm, 640mm, 530mm	720mm, 640mm, 560mm and 480mm
NCHRP 350 test 3-11 Approved	Yes	Yes	Yes	Yes
Post Spacing	2m or 3.8m or 5.1m	3.2m or 2.4m	2m or 3m or 5m	2.5m
Dynamic Deflection	1.6m (2m post spacing) 1.8m (3.8m post spacing) 2.31m (5.1m post spacing)	2.4m and 2.6m (3.2m post spacing, Height#1 and Height#2 respectively) 2.7m (2.4m post spacing Height#2)	2.06m (2m post spacing) 2.4m (3m post spacing) 2.8m (5m post spacing)	2.7m

Table 1. Systems characteristics and performance on NCHRP 350 Test 3-11

U.S. High Tension Cable System

The U.S. High Tension Cable System is a three-cable system. It is currently produced by NUCOR Marion Steel Inc., and uses Rib-Bak™ cable line posts and 0.25-inch diameter

U-shaped hook bolts to guide the cables at the desired height. The manufacturer describes two procedures to install the posts: (1) directly embedded in the ground (driven), or (2) using cast-in-place or pre-cast concrete socket foundations. When using concrete foundations, it is important to get the socket flush with the concrete in order to avoid having the top portion of the socket exposed and to allow posts to shear off rather than bend. It is recommended that the foundation reinforcing bars be tied together to assure their proper placement and the resistance of the foundation.

The manufacturer recommends using non pre-stretched cable, but pre-stretched cable can be supplied upon request. A template to attach the hook bolts at the correct height is helpful in the installation process because the posts have one hole every inch.

Figure 1. U.S. High Tension Cable System

The system is typically tensioned at 5,600 lb, and anchored with a Texas Transportation Institute's (TTI) proprietary Cable Guardrail Terminal End. TTI's end treatment was designed for rocky or hard soils, and is NCHRP 350 approved (details on TTI's end treatments can be found in acceptance letter of U.S. High Tension Cable System – FHWA website). Upper and lower cables are recommended to be located on the side of the post closest to the roadway, leaving the middle cable on the opposite side.

For details on the most recent information about the NUCOR Marion Steel Inc. cable system, contact Rich Mauer, National Sales Manager, Marion Steel Company, or visit the following websites:

- Official website: http://nsmarion.com/
- Multi-state distributor of NUCOR system: http://www.gsihighway.com/nucor

Brifen Wire Rope Safety Fence (Brifen WRSF)

Brifen USA manufactures four-cable and three-cable systems, both are NCHRP 350 approved. The sites visited had only installed the four-cable system. The Brifen (**Bri**tish

Fence) WRFS uses an exclusive S-shape post in its TL-3 version. The manufacturer recommends only pre-stretched cables.

Figure 2. Brifen Wire Rope Safety Fence System

Posts are installed in concrete foundations with a minimum strength of 3,500 PSI or can be driven using a post with a soil plate. In the four-cable system, the three lower cables are interwoven around the posts and the upper cable is placed in a slot on the top of each post. The end treatment is a customary part of the design and extends 19 posts in total: 4 posts for the Wire Rope Gating Terminal (WRGT), and 15 posts for the transition to the line posts.

For detailed information on the Brifen system, contact Jerry Emerson, P.E. Marketing Engineer Brifen USA

Official website in USA: http://www.brifenusa.com/

CASS

CASS (**Ca**ble **S**afety **S**ystem) is a three-cable system by Trinity Industries, Inc. It uses pre-stretched cable, and the posts have an opening in the upper part to accept the cables, which are kept in correct position by wider slot sections at specified cable heights, a plastic cap on the top of the post, plastic spacer blocks, and a steel strap. Posts are installed in steel sockets that can be either driven directly into the soil, or cast in concrete cylinders. TTI's Cable Guardrail Terminal Ends are used to anchor the system.


Figure 3. CASS System

For more information on the CASS system contact Rich Figlewicz, Consultant-Highway Safety Products Division, Trinity Industries Inc.

Official website: http://www.highwayguardrail.com/

SAFENCE

Safence is a 4-cable WRSF system originally developed in Sweden by Blue Systems AB in 1993. Cables in the Safence system are factory pre-stretched. It uses I-section or C-section posts, which can be driven directly in the soil or installed in concrete cylinders. Spacers are placed between the cables to maintain adequate separation. Up to date, crashworthy end terminals have not been developed and tested.


Figure 4. Safence System

For more information on the Safence system, contact Michael Kempen, Vice President Safence.

Official website: http://www.bluesystems.se/indexe.htm

State Visits

The important factors in selecting the sites visited were:

- Variety and length of cable barrier systems installed,
- Experience in maintaining the systems (time after installation),
- Travel time to installation sites, and
- Travel time and accessibility to manufacturing companies.

Ohio, Oklahoma, and Texas, were chosen based on these criteria.

This selection allowed the Scanning Tour to learn about experiences with the three most commonly used cable barrier systems in the U.S.: Brifen Wire Rope Safety Fence (Brifen WRSF), U.S. High Tension Cable System, and CASS. A short section of a less commonly used system -Safence- was also observed in Oklahoma. The Scanning Tour also visited the production plants of the U.S. High Tension Cable System and Brifen USA.

In addition to the abovementioned systems, a fifth cable system called Gibraltar was recently approved by FHWA at TL-3 and TL-4 conditions. At the time the Scanning Tour took place, however, DOTs did not have enough experience using the Gibraltar system to schedule a field visit and gather information on installation, performance, and maintenance.

Ohio

Selection and Application

The use of high tension cable in Ohio was motivated by a series of 11 median crossover accidents that caused 14 fatalities in a 12-mile segment of I-75 starting in October 2001. Crashes were considered unrelated to highway geometry because no common crash cause could be identified.

Ohio DOT considered using standard W-beam barriers, concrete barriers, and high-tension cable barriers to prevent more median crossover crashes. Ohio DOT had removed the generic (low-tensioned) cable system from its standards in 1965 because of safety and maintenance concerns. The generic cable system does not protect against second hits until it has been repaired. Also, Ohio DOT did not have personnel with knowledge on the generic cable system.

Given these options, and based on a combination of estimated costs and expected performance, Ohio DOT decided that the most appropriate barrier for median crossover protection along I-75 was the high-tension cable.

Ohio DOT decided to install the Brifen WRSF system, because at the time it had been proven for more than 15 years in European countries and Australia, and it works under specified maximum deflections. The system is also NCHRP Report 350 accepted, and reduces the concerns of second hits. Ohio DOT was able to draw on the experiences of North Carolina and South Carolina. Also, Oklahoma DOT provided information on the Brifen system, since they installed the first segment in the United States.

Estimations made by Ohio DOT indicate that cable median barrier systems are more cost effective and less damaging to vehicles than many other median barrier systems. Cable systems are said to be much cheaper than concrete barriers and prevent vehicles from bouncing back into the road lanes.

Moreover, geometric characteristics on Ohio's freeways are favorable to cable barrier systems, where most freeway medians are 60 feet or more in width, with slopes of 6:1 or flatter, and with a traversable ditch, usually located in the center of the median.

The reduction in the number and severity of the crashes is Ohio DOT's primary safety objective. The "ODOT Business Plan 2004 & 2005" specifies these goals, among others:

- To reduce the frequency of crashes by 10 percent,
- To reduce rear-end crashes by 25 percent,
- To reduce the crash fatalities to not exceed one fatality per 100 MVMT.

Median barriers in Ohio have helped address these goals by reducing the annual number of deaths caused by median crossover crashes by 17 (16 percent of the total number of crash fatalities).

<u>Warrants and Criteria</u>

Warrants, based on a benefit-cost analysis, are used to select candidate locations for cable barriers, rather than deciding on a case-by-case basis. High priority is given to installations on multilane roadways with median widths less than 76 feet, and traffic volumes exceeding 36,000 AADT. Multi-lane roadways with median widths between 76 feet and 84 feet, traffic volumes greater than 26,000 AADT, and with a poor crash history are also considered for high-tension cable installation.

High-tension cable barriers are also considered for add-lane projects on freeways, if the new traffic lanes are added on the median side. The resulting reduced median width may meet barrier warrants.

Ohio DOT has also decided to retrofit safety "hot spots" with cable barriers to reduce the severity of crashes. On the other hand, cable barriers are not considered for roadside protection, because the numerous driveways in non-fully controlled roadways would require more end terminals, and ultimately more expensive systems.

Design and Construction

Ohio DOT designs high-tension cable barriers specifically for each site. No standard detail drawings have been developed yet. Cable barrier is bid based on maximum dynamic deflection and NCHRP 350 test level (TL-3 is currently used as the standard because most hits don't involve trucks). No differences between 3-cable and 4-cable systems are specified in the bidding process.

Ohio DOT originally believed that the ideal location for cable median barrier was the bottom of the median ditch. However, some concerns arose because the drainage structures are often installed at the same location, and mud and wet conditions can make repairs very difficult for maintenance crews. To avoid these problems, the cable barrier is placed at least 8 feet from the bottom of the median ditch, although Ohio DOT doesn't recommend the use of mid-slope barrier at locations where the median slope is steeper than 6:1. Mid-median or a single run of a shoulder mounted barrier are the current preferred placement locations. Shoulder mounted cable barriers may require dual runs, one on each side of the median, as the cable system has not been tested for hits coming up ditch on the backside.

Current Installations

To date, three different high-tension cable systems have been installed in Ohio: Brifen WRSF, U.S. High Tension Cable System, and CASS. In general, it is highly recommended to use socketed posts instead of driven posts for all systems, despite some difficulties pulling posts out of the sockets in wet conditions.

Brifen System

A Brifen WRSF cable barrier was installed in the median along 14 miles on I-75 by the year 2003. I-75 is a six-lane freeway with 4-foot paved median shoulders and a 60-foot wide ditched median with 6:1 slopes. The barrier was installed on the side of the median slope at 10 feet off the center of the ditch, with a post spacing of 10 feet 6 inch, and a design deflection of 7.9 feet. The barrier flips sides depending on the existing structures along the road. Existing barriers were kept separate from cable system.

Climate conditions in Ohio are suitable for the standard Brifen installation, where the frost line and the depth of concrete posts are both 36 inches.

Most of the Brifen posts were originally driven on the median slopes, but based on the maintenance experience after several hits, it was decided to install concrete foundations on those damaged locations and use socketed posts to facilitate repairs.

Since the Brifen system was installed, about 200 hits have been reported, with no fatalities and one penetration.

In January 14, 2004, a passenger car destroyed 14 Brifen posts and penetrated the barrier. The cause of the penetration was not clear from the site evidence. Cables sagged to approximately one-half of the correct height. District 8 did repairs two months after the accident. According to information provided by Richard Butler from Brifen USA, the concrete foundations were retrofit, and yielded due to their lack of depth and low resistance. This condition caused the concrete footers to move in the soil, thus not allowing the posts to bend, and creating a ramp for the vehicle to "ride up" and over the system.

U.S. High Tension Cable System

U.S. High Tension Cable System was installed in the median along 12 miles of I-270 by October 2004. The posts were placed at the edge of the paved shoulder and socketed in concrete foundations. Post spacing is 6.5 feet for a design deflection of 6.5 feet. More than 30 hits have been registered since installation with no fatalities or penetrations.

U.S. High Tension Cable System posts shear as a consequence of a hit, allowing cables to maintain their height. However, posts at some locations have bent, allowing the concrete foundation to be pulled out of the soil. Other posts have also sheared off at the bottom of the sleeve, particularly during the spring thaw. Installing the locking bolts in the U.S. High Tension Cable System can increase repair time, but they hold the cable at its proper height more securely than the other systems. Otherwise, the high-tension cable can cause the posts to "float" where the barrier crosses local depressions.

Many of the TTI anchor foundations were redesigned and retrofitted by the cable manufacturer because some concrete foundations became loose and moved. A check using Marion Steel's meter revealed that in one occasion the cable was not properly tensioned, but no conclusive causes were found. Tension checks need to be conducted on a regular basis to ensure proper service conditions. It was observed that Ohio DOT overlapped ends of cable barrier behind the guardrail at some locations.

Rainy weather did not permit any close inspection of the installed U.S. High Tension Cable System.

CASS System

Three miles of the CASS system were completed in October 2004. The barrier was placed at the edge of the paved shoulder on an asphalt mow strip. Posts were installed in sockets with concrete foundations and spaced 10 feet with a design deflection of 7.9 feet. Anchor movement has not been a problem, even though the anchor system is also based on the same TTI design used for the U.S. High Tension Cable System. At some locations, CASS posts have bent inside the socket. Based on information provided by CASS manufacturer, posts will bend 99.9 percent of the time at or near ground level, and they are not intended to shear.

About 25 hits have been recorded in the 3-mile stretch with the CASS system with no fatalities or penetrations.

Maintenance

At locations with cable barrier, about 12 percent of the crashes resulted in injuries (mostly minor injuries), and no fatalities have been recorded. The total number of crashes has increased by about 30 percent since the cable installations, and according to Ohio DOT, this increase was attributable to the cable presence.

A document titled "Ohio DOT Field Visits to Cable Median Barrier Projects" contains detailed information on the observations and results of several field visits during February and March 2005 (See Appendix 2). The report concluded that all high-tension cable barrier systems being used are performing satisfactorily and there is no clear preference for one particular system.

State Maintenance forces repair the Brifen cable installation in Ohio. Typically, repairs are done 1 or 2 weeks after a crash in good weather, and up to 2 months after a crash in bad weather conditions. Most crashes require 4 - 5 posts to be replaced, but as many as 43 posts have been damaged in one crash on the Marion system[3]. A worker was injured during one repair of the Brifen system because an improper weaving technique was used.

Mowing and snow plowing is a concern that is recommended to be addressed at the design stage. With regards to Ohio DOT, snow plowing has always been done for the full shoulder width, thus top mounted barriers are subject to snow damage.

Emergency Vehicles

In relation to response times of emergency vehicles, roadway conditions in areas where high-tension cable barriers have been installed are favorable, since interchanges are typically closely spaced. However, in some cases emergency crossovers are located every 1½ miles and the cable runs are terminated at those crossovers.

Visit to NUCOR Marion Steel Inc.

NUCOR Marion Steel Inc. is the current producer of the U.S. High Tension Cable System. On June 3, 2005, NUCOR bought Marion Steel Inc. and about two months later it also bought SAFERoads, which previously manufactured and sold the system. NUCOR Marion Steel Inc. is committed to continue the production and development of the U.S. High Tension Cable System.

The visit to the NUCOR Marion Steel plant, in Marion, OH, was divided into three main parts:

- A meeting with the company representatives,
- A tour through the plant, and
- An inspection of a short piece of the U.S. High Tension Cable System installed in the company parking lot.

[3] In a related comment, it was mentioned that Minnesota State Patrol tags damaged items with the accident report number to facilitate the insurance claims. Funds are returned to the district budget

Details on installation procedures and characteristics of The U.S. High Tension Cable System are included in the product Installation Manual. However, since some of the comments and recommendations given by the company representatives on the use and installation of the U.S. High Tension Cable System are not contained in the Installation Manual, they are included here:

- Development efforts on the U.S. High Tension Cable System are focused on the improvement of the post resistance and stiffness. More resistant and brittle posts will break off rather than bend.

- NUCOR Marion Steel Inc. hopes to reduce the dynamic deflection to 3 feet within the next 3 years. However, it was pointed out that less deflection results in more vehicle damage because less energy is being absorbed by the cable system.

- Limiting the distance between end treatments to ½ mile is preferable. This recommendation helps to control deflections, and also reduces the amount of system that can be taken out by a hit on a terminal.

- For concrete foundations, it is advisable to punch the holes in the soil instead of drilling them, because it compacts the soil in the hole and leaves less spoil.

- Latest version of the post sleeve is cheaper but more flexible because of its cylindrical shape. The previous version was square.

- NUCOR Marion Steel Inc. is supportive of the use of driven posts. Their posts are often driven in other applications such as signage support.

- Using reinforcing bars in the concrete foundations is highly recommended by NUCOR Marion Steel Inc. to increase longevity.

- Representatives from NUCOR Marion Steel Inc. recommended non pre-stretched cable over pre-stretched cable. It was stated that after a number of crashes, the standard cable would be stretched as much as the pre-stretched cable. The manufacturer said that eventually both will be equivalent and the initial cost of the pre-stretching process does not result in system benefits.

- NUCOR Marion Steel Inc. is coming out with a new digital tension meter manufactured by DILLON Inc.

The main processes in the NUCOR Marion Steel plant to manufacture steel, and obtain different forms of steel elements for the cable barrier systems are shown in Appendix 3.

Oklahoma

Selection and Application

The first installation of high-tension cable barrier for median crossover crashes in the United States was completed in Oklahoma in 2000. A median crossover barrier was required along the Lake Hefner Parkway in State Highway 74, Northwest Oklahoma City, in response to a series of crossover crashes that left 4 fatalities between June 1997 and May 2000. At this location, State Highway 74 is a six-lane freeway with a grass median between 36 feet and 42 feet wide, and with volumes of 108,000 AADT as of 2000, and increasing.

Local residents were concerned about blocking the scenic view of the lake, for which concrete or guardrail barriers were not deemed a viable option. High-tension cable systems were considered appropriate because they not only can reduce crash severity, but also complied with the aesthetic requirements.

Oklahoma DOT selected Brifen WRSF, and FHWA approved the experimental use of the high-tension cable in a 1,000-foot section. A private contractor carried out the installation. At the time, the end terminals were not NCHRP 350 approved, thus existing structures or additional barriers shielded the end terminals.

Deflections are an issue for the generic cable because it limits the locations where this system could be used. Oklahoma DOT stated that while the generic cable typically deflects between 11 feet and 12 feet, deflection for the Brifen high-tension cable system is about 6 feet to 8 feet. Also, in contrast to the generic cable system, high-tension cable is designed to remain serviceable after a first hit.

Warrants and Criteria

Priority for median barrier installation is set based on location, frequency, and severity of crashes. For location selection, the Traffic Engineering Division prepares a series of maps showing the locations of crossover collisions (a crossover collision was defined as "run-off road left" followed by a collision on the other side). These locations were then ranked by severity index, and selected in priority order.

Design and Construction

Cable system selection follows a bidding process with specified post spacing. There is not a consensus on whether the number of cables used by the system should be part of the specifications or not. Satisfactory experiences in Ohio with 4-cable systems, and the elevated number of truck crashes, have suggested that continuation with this type of cable barriers can be positive. However, not enough experience on 3-cable systems has been acquired yet.

Current Oklahoma DOT standards require the systems to be NCHRP 350 TL-3 approved. There is some interest in moving to TL-4 requirements, but future change to TL-4 need to be further studied because the cable height would be raised and performance with small cars is a concern.

Location of the barrier has been a major concern and is currently determined in a case-by-case basis. Oklahoma DOT has observed a tradeoff between barriers at or near the median center, which can reduce the potential for nuisance hits, and barriers on the edge of shoulders, which can reduce the amount of sand and fine particles getting into the foundation sleeves, easing post replacement. At some locations where the cable barrier has been placed near the median center, median drains were adjusted to allow the cables to maintain a level profile while maintaining hydraulic capacity. In some cases, steep median slopes have been reduced to a maximum of 6:1 for cable installation.

Barrier posts are installed in socketed concrete foundations. Driving posts can reduce initial costs, but it is believed that maintenance costs could be higher in the long run. Oklahoma DOT prefers "punched-in" holes to drilled holes. As mentioned previously, this method compresses the soil around the hole and improves resistance.

The use of high strength concrete, instead of reinforcing bars for post foundations in the Brifen system, has shown good results. No broken foundations have been reported up to date. CASS installation used reinforcing bars in footings, but no data is available for evaluation yet.

Existing safety devices, such as sand barrels or guardrail barriers, remained in place after cable installation and were shielded by the cable. Mow strips have been placed under the cable barrier in two installations, but Oklahoma DOT doesn't believe it is essential for the cable systems in all projects. It is recommended to place reflective tape on the plastic cap of the posts to reduce hits at night and help emergency vehicles to identify crossover points.

<u>Current Installations</u>
Currently, there are three different high-tension cable systems installed in the Oklahoma City Metropolitan area: Brifen WRSF, Safence, and CASS System (See Appendix 4). Oklahoma DOT designed the installations for Brifen and Safence systems, but the manufacturer – Trinity Industries Inc, designed the CASS installation. In terms of performance, Oklahoma DOT indicated satisfactory results for all three systems. Crash reports summarized below included data as of July 31, 2005, and can be found in detail in Appendix 5.

<u>Brifen System</u>
The first Brifen test installation was extended from 1,000 feet to 7 miles in 2001. Cable was installed in two sections of 2 miles and 5 miles long between end treatments. No negative experiences have been reported due to the long cable runs. The barrier was not located at the center of the median, as the first 1,000-foot stretch was, but on a paved mowing strip just outside the southbound shoulder. This placement was also preferred over the center median because the drainage inlets created a slope too steep for an adequate installation (see photographic material in Appendix 6).

Oklahoma DOT provided to the Scanning Tour participants two reports about the Brifen installations:

- "Brifen Wire Rope Safety Fence Final Report" by Faria Emamian P.E. Engineer Manager in Oklahoma DOT, dated March 2003 – this report includes a detailed collision analysis, and maintenance and repair issues on the 7-mile stretch on the Lake Hefner Parkway (See Appendix 7).

- "Oklahoma DOT Experience with Brifen Wire Rope Safety Fence on Lake Hefner Parkway in Oklahoma City", by Randy B. Lee, P.E. Division IV Traffic Engineer in Oklahoma DOT, dated June 24, 2004 – Mr. Lee was involved in the maintenance of the Brifen installation. The report includes some comments on the system (See Appendix 8).

Some of the most relevant comments from these two documents, as well as additional information provided by Oklahoma DOT related to the Brifen installation are described below:

- As of May 10, 2004, a total of 238 hits have been reported in the system, requiring replacement of 1279 posts, for an average of 5.3 posts per hit.

- As of June 24, 2004, the average cost charged by the maintenance contractor for the replacement of each post was $51.00.

- No fatalities and 3 injuries have been reported. This represents a significant reduction in crash severity compared to a similar time frame before the barrier installation.

- It was estimated that police accident reports have only been filed on approximately 30 percent of the hits, indicating very light vehicle damage.

- One person using only hand tools usually makes a 5-post repair in 15 minutes. It is not recommended, however, to lift the cables by hand for safety of workers.

- The system has remained serviceable after multiple hits at the same location.

- The use of long distances between anchors has not generated any loss of cable tension, nor turnbuckle damage after the hits.

- The largest vehicle to impact the barrier was a full size school bus, which was redirected safely after the driver had a heart attack.

- In a few cases, cables dropped down to the ground when many posts were knocked out. (Repairs were made within 2 hours, as required by the contract for these types of hits). It should be noted that typical hits don't have this effect on the cable barrier.

- The mow strip placed under the cable system (4 feet wide and 4 inches thick) is not effective since hand mowing is still needed. A soil herbicide is mentioned as a possible solution.

- Low front vehicles, such as sports cars, can potentially penetrate the barrier because their suspension is compressed at the bottom of the ditch and the bumper can underride the lower cable.

A second installation using the Brifen system was completed in September 30th, 2004, along 6.3 miles on I-35 in the Norman area, Cleveland County. Twenty one hits have been reported since installation, with one property damage crash and no fatalities or injuries. During the last 5 years prior to the barrier installation, 6 fatal, 16 injury, and 9 property damage crashes were reported in this stretch of road.

<u>SAFENCE</u>

A one-mile test of the Safence system was installed as a demo, promoted by the manufacturer, along I-35 north of Purcell, McClain County (see Appendix 6). The barrier was completed on the same date Brifen's second installation was completed, September 30, 2004. Because of its short length, only 3 crashes have been reported since cable installation, all of them without injuries or significant vehicle damage. During the last five years prior to the barrier installation, 1 fatality, 5 injuries, and 1 property damage crash were reported in this stretch of road. Similar concerns to those found in Texas when lifting CASS cables by hand for maintenance activities may be expected with the Safence system (See CASS System Section in Texas Visit below).

<u>CASS System</u>

The CASS system was recently installed (August 26, 2005) on I-35, McClain County. Up to date, no crash data is available to provide performance results on this system. A total of 3 fatal, 1 injury, and 3 property damage crashes were reported the last five years prior to the barrier installation.

<u>Maintenance</u>

The maintenance on the Brifen systems is contracted out. Oklahoma DOT does the maintenance on the other systems. Repair parts have been readily available and are delivered in a timely manner. The average repair takes about 20 minutes. So far, the repairs have only involved replacing posts and some of the hardware associated with posts.

Maintenance staff generally prefers the cable barrier to be located in the middle of the median. There have been no significant wintertime maintenance problems.

See Appendix 9 for Oklahoma's Questionnaire responses.

Emergency Vehicles

To minimize the effect of the limited number of crossovers for emergency responders, Oklahoma DOT has considered the option of flipping side of the roadside barrier and overlapping the end treatments at the flip points to provide turnarounds. This would be done at overhead bridges or other sites where topography provides convenient turnaround locations.

Visit to Brifen USA Inc. in Oklahoma City, OK

Brifen representatives met with the Scanning Tour at the Brifen USA plant, located in Oklahoma City. Some of the comments discussed in the meeting prior to the plant visit, as well as recommendations and comments at the plant are included below:

- Brifen recommends the use of pre-stretched cable for the barriers. The pre-stretching process takes slack out of the cable and equalizes loads in the 21 wires of the rope.

- There is a mini-anchor effect generated by the cable weaving. Friction between cable and post dissipates some energy from hits. Testing has shown that tension from a test-level impact does not transfer beyond 70 posts from the impact location. This helps to keep the effect of a hit under a limited section in a long stretch of the Brifen system.

- Crash tests were performed on 600-meter sections (about 2,000 feet), which is considerably longer than the 100-meter sections used in standard NCHRP 350 TL-3 test.

- Although early systems were installed with 14-inch by 36-inch foundations, the standard is now 12 inches by 30 inches as tested with the TL-4 system. TL-4 version was reinforced with a u-shaped rebar ring welded to the bottom of the steel socket. Driven posts are available, but not recommended due to higher maintenance costs.

- It was not recommended to use pre-cast concrete footings because it is not easy to perfectly match the footing volume with the volume of the hole in the ground. As a consequence, footing can become loose and move after an impact.

- Turnbuckles can be placed at posts. Special posts with extra wide slots are provided in such cases. However, no more than 2 turnbuckles should be placed within 10.5 feet to avoid a single crash hitting more than one connection.

- Brifen uses solid body turnbuckles, which are claimed to be sturdier than open body turnbuckles.

- Standard line posts can be used down to a 200-meter radius (about 656 feet).

- Construction inspection is very important.

- For median locations it is recommended to install the Brifen WRSF at least 10 feet from the bottom of the ditch on a slope no steeper than 6:1.

- A black plastic "excluder" (resembles a black Frisbee) is placed at the base of the post and covers the sleeve. It is meant to keep out larger objects. Finer elements may get into socket, but there is no need to clean them other than when the posts are being replaced after a hit.

- There have been 300 hits on the Hefner Parkway system, which is at the shoulder. The proportion of hits has been roughly 2:1 nearside vs. far side.

- Minnesota DOT asked if a TL-5 test would be conducted. Brifen doesn't think the investment is justified. Also, there are some substantiated reports of the TL-3 system containing and redirecting trucks well beyond the TL-3 weight.

- It is possible to terminate a Brifen barrier by connecting it to a guard rail.

- Current cost per post is $18.30. Other parts cost less than $5 per post (as of August 2005).

- During the field trips, it was observed that the top of the concrete foundations are constructed with a convex top (or dome). The height of this dome needs to be limited because it affects the ground clearance of the bottom rope, which is critical.

Texas

The Scanning Tour visited the Weatherford Area Office in Texas[4]. This office is part of the Forth Worth District of the Texas DOT. It is located west of Fort Worth and is responsible for two counties – Parker and Palo Pinto. There are 52 maintenance, and 19 Design/Construction employees on staff.

<u>Selection and Application</u>
In Texas, the Safety Bond Program, approved by voters in 2003, is providing safety improvement projects totaling over $600 millions. Reduction in the crash frequency and severity is one of the primary goals of the Safety Bond Program. It was mentioned that almost all fatalities (about 96 percent) in the interstate system had been cross median related.

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[4] Due to time constraints, a visit to the Trinity Industries Inc. facilities in Dallas, TX, was not possible for this Scanning Tour. However, representatives from Trinity Industries Inc. have been supportive to this Scanning Tour and provided the participants with information on their CASS system.

Warrants and Criteria

Median barrier projects are supported by warrants. The Weatherford Area Office, in coordination with the Traffic Section at the Forth Worth District Office, analyzes traffic reports and crash data to prepare a list of the candidate locations for improvements. Currently, cable median barriers are warranted on freeways only, in particular, freeways with medians narrower than 44 feet (measured between edge stripes).

Cable barriers are thought to be cost-effective. The improvement in safety translates in lower crash severity and reduction in total expenses, but a precise evaluation will require more time and data to account for maintenance costs in the long run. Under a high hit rate, it is expected that cable barriers are more expensive compared to concrete barriers. However, low severity of crashes with cable barriers seems to be also a decisive factor in its favor.

Design and Construction

Selection of cable system is based on a bidding process. Requirements for bidding companies are based on price, NCHRP 350 TL-3 approval, and maximum deflection (typically 8 feet). No distinction is made between 3-cable and 4-cable systems in the bidding process. TXDOT has not planned to change NCHRP 350 requirements from TL-3 to TL-4 because cable performance under TL-3 has been satisfactory for all types of vehicles.

TXDOT specifications for cable barrier systems are included in the Special Specification 5084, Miscellaneous Constructions Section, in the document "Texas DOT specification 2004". A copy of the specification sheet was provided to the Scanning Tour (See Appendix 10).

Cable barriers are preferred near, but offset from the edge of the shoulders. Brifen and CASS systems were installed at about 14 feet from the edge of the inside travel lane, where typical median shoulder is 6 feet wide. This placement provides a more consistent profile than installations in the center of the median, because it prevents difficulties caused by drainage structures and uneven ground, and reduces chances of weaker soils at foundation depth. Sharp changes in the profile cause significant variations in the height of the cable above the ground, since the system is under high tension and cable tends to follow a straight line rather than the actual profile line over short distances.

The longest run of cable between anchors is about 4 miles. The stretches of cable are installed from bridge to bridge with no crossovers, except for one location, and barrier is usually lapped behind the approach guardrail or is shadowed by the downstream end of the bridge.

On future works, a more convenient layout for emergency vehicles has been planned. Cable will change median sides at each overhead structure, and end points will overlap to allow crossovers.

A 4-foot wide by 3-inch thick asphalt mow strip was constructed to help reduce cable barrier maintenance. It is believed that the strip also makes cable barrier more noticeable for first responders, who may suddenly need to cross the median in the case of an emergency situation. Reflective tape on top of the posts is also recommended to increase barrier salience and avoid such situations.

It was recommended to control the water level at mow strip to avoid premature asphalt deterioration and additional maintenance. Even though cable barrier doesn't need to be mowed because of the asphalt strip, TXDOT protects the installation from damages caused by mowing contractors by charging them $100 per post damaged.

Drilling post foundations was the leading activity during installation. About 50 12-inch-diameter holes were drilled per day/drill truck. Posts were installed in reinforced sockets with concrete foundations, including locations with hard rocky soils. A defective 36-inch foundation on sandy soil was reported pushed out of the ground in I-635, near Dallas.

To adequately secure the turnbuckle connections, Brifen recommends fully engaging the threads into the turnbuckle before making final connections. Because cable is pre-stretched, it doesn't need much length to be pulled out to achieve the required tension, and not much more thread engagement will be gained while tensioning.

During these initial installations, it has proven important to be familiar with system details during the installation process, in order to timely address contractor's questions. Representatives from Brifen and CASS were also present during installation to give technical support as needed. At one location, a Brifen anchor foundation was built with flat top instead of a 12-degree inclination. Brifen took engineering responsibility and corrected the structure using a special wedge. In some situations, installation misunderstandings or errors were avoided by active on-site guidance to the contractor from manufacturer's representatives. Some examples of these misunderstanding or errors were related to the purpose of the inspection hole in the field splice, the number of required bolts for the anchor, and the requirement for threads showing beyond the shoulder of the nuts.

The contractor is responsible for any damage to the barrier prior to final acceptance. This contractual requirement protects DOT from additional costs during installation, but it may delay completion of functional smaller sections of barrier, and encourage contractor to finish all post installations first, and only put the cable up just before project acceptance. This was noticed to be an issue in the Weatherford Area Office projects.

In order to incrementally open barrier to service, future modifications in long projects may include accepting small road sections as soon as the cable installation is completed. The contractor put up all the posts before installing the cable on the first 21 miles installed in their area. On future projects they will accept completed segments.

Current Installations
21 miles of cable barrier were installed in Parker County: Brifen (10.5 miles) and CASS (10.5 miles), both on I-20 and I-30 (see photographic material in Appendix 11 and Texas DOT design examples in Appendix 12). Post spacing was 10 feet 6 inch in the Brifen system and 10 feet in the CASS system. The complete project cost was $1.4 million for the 21-mile roadway stretch, where typical volumes are close to 68,000 AADT.

It was decided to install cable barrier along I-20 in Parker County for the following reasons:

- History of crashes, including crossover and head-in crashes (An average of 2 to 4 crashes were reported each week).
- The junction between I-20, I-30, and I-820, is very complex and generates a concentration of crashes in the surrounding areas.

Despite few very specific cases with minor issues, performance of both Brifen and CASS systems is similar and very satisfactory. No vehicles have penetrated the barrier.

Press reaction to cable performance has been balanced. Initially, poor press pointed out concerns due to lost time for emergency response. However, good comments have been written after significant crashes that did not go through the median. It seems that cable barriers have good acceptance among the public in general. The community has demanded cable installation at some locations with severe crash history.

Brifen
As many as 30 posts or more have been taken out in the Brifen system after a hit, but about 15-20 posts are damaged by an average hit in both systems. Performance of the high-tension cable systems is kept up to date by filling out a repair log and an accident report form for each hit (See Appendix 13). Funds recovered after damage claims are deposited into the General Fund unless damage is higher than $25,000.

Some crashes have reportedly left the Brifen cable laid down after some impacts. TXDOT has observed sag in both systems after a few significant hits, but sag has been more common in Brifen. No detailed information was given on the actual cause of the sag in Brifen system, but the cable straightening when taking posts out (loosening the weaving), and the fact that bigger vehicles have hit Brifen and damaged more posts, may both be contributing factors to this issue.

On one occasion the Brifen system was hit by a large truck. The system stopped the vehicle, but a cable came loose from the turnbuckle. The male end of the threaded connection was left intact after the separation, and it seemed that the connection failed because it was shallowly threaded. A special splice piece was fabricated to repair the separated cable.

At a few locations, Brifen posts have bent and become stuck inside sockets on impact, making it difficult to pull them out and complete the maintenance. The plastic spacer pegs used in the Brifen system have broken off easily. An increase of the pressure on the pegs caused by the weight of the cable or changes in elevation may be enough to overcome the peg resistance. Dust covers in the Brifen system are reportedly difficult to get off the posts, and sometimes it is more troublesome to reuse them than place new covers instead. Richard Butler from Brifen USA commented that the problem with the posts was related to component manufacturing tolerances and that it was corrected. The chemistry of the dust covers was modified to eliminate difficulties removing them from the posts.

The Brifen spreader bar is useful for replacing posts when 2 workers are doing the repairs, but the bar is not required if a 4-person crew is on the job. Special attention needs to be given to the cable weaving when replacing many posts in the Brifen system. A recommendation to ease the weaving process is to replace posts every other position, and then weave the cable as the intermediate posts are placed. Failing to follow an adequate weaving technique may cause significant delays to repairs.

<u>CASS System</u>
The CASS system has also been hit by large vehicles. In August 2005, two 18-wheelers and a GMC Jimmy SUV were involved in an incident on I-20. The cable system prevented an 18-wheeler from crossing the median. The cost repair was estimated at about $2,000, and no injuries were reported.

Posts in CASS system beyond the actual impact zone can be opened up at the top during the collision. Sometimes the posts can be straightened back, but need to be replaced otherwise. Trinity Industries Inc. does not recommend trying to straighten bent posts. Plastic spacers between cables in the CASS system are compressed and sometimes bent. In the Texas installation, CASS cables are too tight to be lifted by hand. When repairing the system, it is not recommended to lift cables over the post by hand because this places hands and backs in potentially vulnerable situations.

<u>Maintenance</u>
Maintenance is carried out by State forces, which were initially trained by manufacturers. Current TXDOT maintenance employees are now training new workers, assuring knowledge transfer over time.

Repairs are generally done the next working day, during daytime. Partial repairs are recommended in bad weather conditions to at least insure cable height is correct until the full repair is done. Wintertime issues are not a significant concern for cable barriers in Texas because there is usually not significant snow accumulation or frost heave effect.

Additional mechanical assistance, such as boom trucks or tripods, will facilitate the repairs significantly, in particular to pull stuck Brifen posts, and to lift and place cables in the slot of CASS posts.

Cable tension is not commonly re-checked after repairs, but some readings have been taken in the field. Differences in the readings from CASS (Digital) or Brifen (Analog) meters have been found to be about 500 lb, but it is not known which meter is more accurate. As a preventive measure, TXDOT recommends requiring the meter manufacturer to calibrate the device before delivery, preferably in the United States.

A stock of repair parts is continuously kept indoors in the Weatherford Area Office (posts are stored outside). A customized trailer with individual compartments is currently used to carry all parts, including posts, with a capacity of about 40 posts. Parts for both Brifen and CASS are purchased directly from the manufacturers, which offer lower prices than third-party suppliers.

From the maintenance point of view, cable systems are effective but intensive to maintain. However, workers believe reduction in fatalities is worth the additional maintenance work compared to other types of barriers. It was also noted that maintenance crews would rather respond to repair the cable system than to provide traffic control for a fatal crash response.

<u>Emergency Vehicles</u>
TXDOT recommends informing first responders about the need to keep cable barrier systems and to avoid cutting cables, as well as offering educational sessions to tow truck drivers and other interested groups. It is also advisable not to loosen the turnbuckle once the cable is in place because pulling it back to its previous tension is very difficult. TXDOT conducts meetings with Fire Departments and tow companies on a regular basis to reinforce the message and since the two companies have considerable turn over in personnel.

General Conclusion

Based on the experiences shared by DOTs in Ohio, Oklahoma, and Texas, as well as the product information provided by manufacturers of the U.S. High Tension Cable, CASS, and Brifen systems, the following general conclusions can be drawn on the high-tension cable barrier for median crossovers:

- In recent years, there seems to be an increasing trend in median crossover crashes in all 3 states visited and all 4 states that sent representatives to the tour.
- The median cross over protection systems can reduce the fatalities and life changing injuries due to median crossover crashes.
- High-tension cable systems have been successfully used for median crossover protection on highways with wide medians and flat median slopes. There is potential for use in other conditions, but more experience and performance testing in the U.S. are needed.
- The general performance of the cable barrier systems, at redirecting or stopping vehicles, seems to be excellent.
- All cable barrier systems observed in the Scanning Tour (Brifen, U.S. High Tension Cable System, CASS, and Safence) seem to be perform similarly when hit by passenger vehicles. Further experience and testing is needed to quantify system capacity for heavy vehicles.
- No major drawback of high-tension cable barrier systems was found. Installation and maintenance issues can be improved with experience.

- While maintenance of the barrier system requires workers to be exposed to highway traffic, traffic control and cleaning up after vehicle crashes also requires workers to be exposed to highway traffic. Repairing the barrier is a more satisfying job knowing that the barrier prevented severe injury or even death.
- Warrants for installation of median cable barrier tend to a severe crash history. Such a large potential for installation forces decision makers to take care of worst cases first.
- States are still in the learning process. Information gathered in this Scanning Tour provided valuable knowledge on system characteristics, performance, and maintenance.
- This Scanning Tour has been very useful to guide the participant states in all aspects related to the use of high-tension cable systems in their roadway systems. Similar scanning tours are recommended in the future for addressing particular issues in transportation.

In addition to those lessons learned, more experience and data is needed to draw conclusions or make improvements on the following aspects:

- The in-service performance evaluation (ISPE) for any system has not been completed. Performance in the long run is not known.
- Results from long-term benefit-cost analyses are not yet known.
- Differences in performance and long-term maintenance issues between cable systems (3-cable and 4-cable systems) are not completely clear.
- Designs for cable systems at points of interaction with other structures such as guardrail, bridge piers, or sand barrels, are not completely standardized.
- Practices dealing with crossover requirements from first responders and crossover gaps are still being improved.
- Guidelines for optimum location of cable barriers in various types of median widths and slopes need to be developed.
- It is not known how updates in NCHRP 350 criteria can affect the systems and their usage.
- A new national guideline for median barrier warrants by AASHTO is anticipated. The guideline is a tool that can help states in identifying their needs for median barriers. It will also provide States the flexibility to customize their warrants based on local data and factors such as highway systems, crash history, politics, and public opinion.

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Appendix 1

Participants in Meetings

Date: August 29, 2005
Time: 2:30 PM EDT
Place: Ohio DOT, Columbus, OH

Name		Organization
David	Piper	Illinois DOT
Deanna	Maifield	Iowa DOT
Chris	Poole	Iowa DOT
Gary	Dirlam	Minnesota DOT
John	Hanzalik	Minnesota DOT
Juan	Medina	University of Illinois
Peter	Amakobe	Wisconsin DOT
John	Bridwell	Wisconsin DOT
Dean	Focke	Ohio DOT
Mark	Hatfield	Ohio DOT
Joe	Glinski	FHWA Ohio

Date: August 30, 2005
Time: 9:00 AM EDT
Place: NUCOR Marion Steel Inc. plant, Marion, OH

Name		Organization
David	Piper	Illinois DOT
Deanna	Maifield	Iowa DOT
Chris	Poole	Iowa DOT
Gary	Dirlam	Minnesota DOT
John	Hanzalik	Minnesota DOT
Juan	Medina	University of Illinois
Peter	Amakobe	Wisconsin DOT
John	Bridwell	Wisconsin DOT
Dean	Focke	Ohio DOT
Rick	Mauer	NUCOR Marion Steel, Inc.
Joe	Glinski	USDOT - FHWA

Date: August 31, 2005
Time: 8:00 AM CDT
Place: Oklahoma DOT, Oklahoma City, OK

Name		Organization
David	Piper	Illinois DOT
Deanna	Maifield	Iowa DOT
Chris	Poole	Iowa DOT
Gary	Dirlam	Minnesota DOT
John	Hanzalik	Minnesota DOT
Juan	Medina	University of Illinois
Peter	Amakobe	Wisconsin DOT
John	Bridwell	Wisconsin DOT
Faria	Emamian	Oklahoma DOT
E.W. “Red”	Miller	Oklahoma DOT
Nabeel	AbuSadah	USDOT - FHWA
Huy	Nguyen	USDOT - FHWA

Date: August 31, 2005
Time: 1:00 PM CDT
Place: Brifen USA, Oklahoma City, OK

Name		Organization
David	Piper	Illinois DOT
Deanna	Maifield	Iowa DOT
Chris	Poole	Iowa DOT
Gary	Dirlam	Minnesota DOT
John	Hanzalik	Minnesota DOT
Juan	Medina	University of Illinois
Peter	Amakobe	Wisconsin DOT
John	Bridwell	Wisconsin DOT
Faria	Emamian	Oklahoma DOT
Richard	Butler	Brifen USA, Inc.
Jerry	Emerson	Brifen USA, Inc.

Date: September 1 and 2, 2005
Time: 1:30 PM CDT
Place: Texas DOT, Weatherford, TX

Name		Organization
David	Piper	Illinois DOT
Deanna	Maifield	Iowa DOT
Chris	Poole	Iowa DOT
Gary	Dirlam	Minnesota DOT
John	Hanzalik	Minnesota DOT
Juan	Medina	University of Illinois
Peter	Amakobe	Wisconsin DOT
John	Bridwell	Wisconsin DOT
Jimmey F.	Bodiford	Texas DOT - Fort Worth District - Weatherford Area office
Alan B.	Donaldson	Texas DOT
John	Cordary	Texas DOT
Jackie R.	Baker	Texas DOT

Appendix 2

Ohio DOT Field Visits to Cable Median Barrier Projects (4/11/05, summary added 4/13)

ODOT's Office of Roadway Engineering Services organized several field visits during February and March 2005 to identify post construction concerns for the first wave of cable median barriers installed in Ohio. Representatives from Central Office's Roadway Engineering, Production, and Safety & Mobility offices, along with district, manufacturer, contractor and FHWA personnel were invited to each meeting.

The purpose of the field visits were an effort to ascertain and monitor any design, construction, maintenance and performance issues so that these lessons could be applied to future projects.

For background information, cable barriers are being considered as standard median protection for ODOT. This is due to the apparent increase in cross median accidents throughout the state.

Even on the national level, AASHTO and NCHRP have been working to develop new Median Barrier Warrants to replace AASHTO's Roadside Design Guide Figure 6.1 (published in ODOT's Location and Design Manual, Volume 1, as Figure 601-2). Because national guidance in providing states with updated guidelines is lagging, several states have implemented their own warrants. Within ODOT, the offices of Safety & Mobility and Roadway Engineering are working together to develop guidelines for Ohio. According to one analysis approximately 500 miles of ODOT Interstate system is a candidate for cable installation.

Several states have had a median protection program in place for at least a few years. The states that have been leading the way on median protection have used generic cable (known as US Customary) because of a lack of other suitable products. This generic cable has been in use by the state DOT's for several decades for roadside applications. Since this product has some major drawbacks, it never really gained favor over standard w-beam guardrail in Ohio. However, ODOT itself has installed the product once, in the median of LAK-90 in the early 1990's.

ODOT accepted existing national guidance on Median Barrier Warrants until a rash of accidents on Interstate 75 north of Cincinnati. Within a 14-month period starting in October 2001 there were 11 fatal cross median accidents. Investigation of each accident report shown no single factor was involved; all of them seemed to be unique. ODOT responded by installing a new and revolutionary type of cable system in this stretch of interstate. It is a tensioned cable system and the product is attractive because it seems to have overcome the biggest concern of the generic system: tensioned cables hold their height after an impact and were poised for a second impact without immediate repair.

The system chosen was Brifen's Wire Rope Safety Fence. It is a product that has been in use for 15 years exclusively outside of the United States (except for it's first US installation, in Oklahoma). Since some of the steel components were only available from the Great Britain, ODOT obtained FHWA approval to install it here. Brifen components are now made in the USA.

Three other proprietary cable systems have now been accepted by FHWA as having met NCHRP Report 350 crash testing criteria. They are the Trinity CASS, Marion Steel SafeRoads and the Safence system. (Safence is not yet made from American materials and is not discussed here.)

ODOT is currently of the position that each of these products performs in a similar manner during impacts and therefore the three products should be bid as equals. However, this position does not account for any installation, repair or maintenance concerns. The field visits were an effort to determine if it is a valid assumption, or if one product stands out a being better and should be recommended.

Ohio is the only state which has each of the three proprietary cable systems installed, allowing us a unique position to compare the products. During the visits, the groups looked at the design, construction, maintenance and performance issues with each barrier.

The three locations visited are Brifen (BUT/WAR 75), Marion Steel (FRA 270/315) and Trinity (LOR 90). Each system and field visit is described below.

Brifen WRSF

Central Office staff met with District 8's Planning, Construction and Maintenance, FHWA's Joe Glinski, and Brifen's Richard Butler on March 7 at District 8. Brifen's 14 mile system was installed in 2003 and its performance had actively been tracked as part of FHWA's approval of the foreign product in 2002. In fact, this office submitted the first of three yearly In-service Performance Evaluation reports to FHWA just prior to the visit. The report concludes the system is working as expected, although it is prudent to continue to gather data for two more years.

The biggest issue raised was that of a recorded accident occurring on January 4, 2005 which destroyed 14 posts, a significant accident on a tensioned system. The accident was caused by a passenger car spinning on wet pavement (a witness said 80 mph), hitting the cable on the near side of the ditch. Somehow the vehicle penetrated the cable, and wound up on the other traffic lanes, causing a second accident. One non-incapacitating injury was reported. In the field visit no one could say for sure if the cable was the cause of the penetration or a fluke of the accident.

The Brifen cables weave through every post, providing additional tension. However, in an accident taking out so many posts, the weave is removed allowing slack in the cable to the point where the cables sagged. The cables sagged to approximately one-half of the correct height. For any cable system the most important key is for the cables to remain at the correct height. A tensioned system can lose its tension and still perform satisfactorily (it becomes a defacto generic system at that point) but if the cables are not at the correct height the system may not engage, or capture, the impacting vehicle.

At this particular accident site, the posts were still missing and the cable still sagged a full two months after the accident. The time between repairs was disconcerting.

District 8 forces perform repairs on this system, and the process they use to repair may contribute to the delay. During design most posts were driving into the ground but as an experiment 2 miles of the 14-mile system were installed with concrete foundations for socketed posts. Socketed posts were offered by the manufacturer as an easier way to repair a damaged post and a segment was installed to test this suggestion. After installation, the District immediately saw the benefits of the socketed posts in accidents because of the ease of repair. The District made the decision to upgrade all impacted posts with a concrete socketed foundation. These types of repairs necessitate extra work because of the concrete involved. Due to winter weather the median was not able to support the equipment needed and the District was not able to repair the affected site. If the District had just driven in new posts to replace the damaged ones, the repairs may have been able to be done sooner.

A complicating factor was that this system had preciously been repaired at this very location using one of these concrete foundations. In the January accident one of these foundations was pulled completely out of the ground. On inspection it did not appear to have any influence on the subject accident. But this particular foundation did not appear to be constructed as to manufacturers specification (12" diameter, 36" reinforced foundation).

Marion Steel SAFEROADS

Roadway Engineering Services, Production, and Safety & Mobility staff met with FWHA's Joe Glinski and Marion's Kevin Mally and Rick Mauer, at the site on February 8, 2005.

Marion's 12 mile system was installed in during several months in the last half of 2003. The contractor had difficulties developing a process for installation, and once that was done construction went at a smoother pace except for problems encountered by the presence of rock near the surface.

Random stops at various locations showed no obvious problems. At unrepaired accident locations it was evident that for the most part the posts sheared at the ground line and slid down the cable to a final resting point, as designed. At accidents sites, the cable seemed to remain in tension and the cables did not visually sag.

However, on March 4 this section was called to an emergency meeting at the I-270 construction office in Grove City. District 6's Construction and Maintenance had called Marion Steel's Steve Conway and Rick Mauer along with the contractor MP Dory's Tom Kuhn to discuss the Construction Engineer's belief that the TTI anchor foundations on the Marion Steel cable project were poorly designed and were moving, with the result of the terminal anchor being pulled out of the ground and a subsequent loss in cable tension in about 5 individual posts of the 35 anchors sets (3 posts each). The TTI anchor is a third-party product and is also used with the Trinity CASS cable. Each anchor foundation is a 2' by 5' deep reinforced concrete dead man weight. To their credit, Marion Steel did agree to redesign the anchor and to offer ODOT a retrofit design for the majority of anchors that did not exhibit problems. This problem is independent of the cable and is being handled separately.

Marion Steel brought out a prototype portable tension meter for the contractor. While running the tension tests on the system, it was observed several cables were rather loose, not up to the ideal 5,600 pounds of tension at 70 degrees F. Some locations were less than 3,000 pounds of force. There may be many explanations for this as in method of taking the force, an uncalibrated meter, and the residual slack of a non-pretensioned system.

On March 18, this office was again called to the field by reports of line post foundations being pulled out of the ground during accidents. Upon inspection of two accident sites that the 3 foundations were damages in a 9-post hit, and 2 were damaged in a 5-post hits. The posts did not shear as designed but were bent over from the force of the impact. The channel design may have provided too much resistance and forced the socket tube to shatter the reinforced concrete foundation. This problem has occurred yet again and is actively being investigated by ODOT.

Trinity CASS

Roadway Engineering Services, Production, and Safety & Mobility staff met with District 3's

Production and Maintenance staff, FHWA's Joe Glinski, Trinity's Gwen Samuels, Robin Cera, and Robert Takach, and Lake Erie Construction's Ray Chapin on March 17 at ODOT's Avon Outpost. Trinity's 3 mile system was completed in October 2004, so its short time and length of exposure to traffic have not given us much data to observe. The system had never been repaired since its installation and there were two locations where 4 posts were missing. The cable remained in tension and the slack was minimal. And the asphalt mow strip led the system to have clean lines and little of the debris noticed at the other cable sites.

The group went to another location where only one post was damaged and replaced it with a new socketed post and reset the cable. Total repair time was under 5 minutes.

The group the found a very recent cross median hit where the vehicle crossed the ditch line and struck the backside of the cable at the edge of the opposite shoulder, damaging another 4 posts. From the tire marks, the vehicle apparently had hit the cable at a relatively high angle and was clearly headed for the opposing traffic lanes when the cable redirected it. The CASS cables remained in tension and was ready for another impact without needing repair.

The TTI anchors on this project seemed to be solid and not moving.

Summary

The associated table summarizes the results of the visits to each of the three proprietary systems. Information on an ODOT installation of a generic 3-strand cable is also listed for comparison. Each of the proprietary systems seems to be performing to NCHRP Report 350 criteria. There is ample evidence all of the systems are preventing crossover accidents.

The intent of the field visit was to identify any potential issues to monitor. Found issues and current disposition of those issues are noted in the table.

Although one of the goals of the field visits was to determine if one system truly out performs the others, many factors complicated the picture and we cannot make such a recommendation at this early juncture. Design placement, Construction issues, Maintenance decisions, short length and duration of exposure prevent us from comparing the systems against each other. For example, ODOT is gathering solid ISPE information only on the Brifen WRSF. The Marion Steel SafeRoads cable installation is very close to the office, allowing perhaps closer scrutiny than the other systems. The Trinity CASS is of shorter length than the others leaving it with less data to compare. In the future, we will attempt to overcome this problem, so a valid comparison may be attempted.

SUMMARY OF CABLE PRODUCTS (Prepared 4/11/05)				
System	**Brifen**	**Marion**	**Trinity**	**Base (generic)**
--------- **PRODUCTS** ---------				
Description	4 cable woven, tensioned and prestretched	3 cable tensioned but not prestretched	3 cable tensioned and prestretched	3 cable un-tensioned and not prestretched
Product History	3000 km of use 20 foreign countries	new system, based on well known and often used frangible sign posts.	new system to USA, but modified from an existing European system	generic cable has been in use in US since 1960's but not an ODOT standard
ODOT Installation	BUT/WAR 75 June 2003 (second in USA)	FRA 270/315 Oct. 2004 (first in USA)	LOR 90 Oct. 2004 (sixth in USA)	LAK 2 1991 (standard used throughout US)
Length of Ohio's Installation	14 miles	12 miles	3 miles	12 miles
Post spacing and crash tested deflection (at that post spacing)	10' 6" spacing 7.9' deflection	6' 6" spacing 6.5' deflection	10' 0" spacing 7.9' deflection	16' 0" spacing 11.2' deflection
Application	on one side of median slope	at edge of wide paved shoulder on one side	at edge of wide paved shoulder on one side	on one side of median slope
Approx. # of hits recorded	160 (6.5 hits/mile/year)	30 (5.0 hits/mile/year)	10 (6.7 hits/mile/year)	n/a
--------- **ISSUES TO MONITOR** ---------				
Issues	1) A penetration of unknown reason has been recorded. **Two additional years of ISPE will watch this.** 2) Cable sagging in severe hits. **District will begin to include information on ISPE.** 3) District decision to replace driven posts with concrete socketed foundation affects timeliness of repair. **Topic is being discussed by CO and District Maintenance.**	1) Replacing of problem anchor foundations. 2) Retrofitting of the remaining anchor foundation to the Project Engineer's satisfaction. 3) Redesign of damaged line post foundations. 4) Keeping watch on the cable tension. **Mfg. is working on but has not yet offered fix for anchor or line posts.**	1) Anchor system is the same as on the Marion Steel system and may be vulnerable to movement as well. **District will alert CO if problem arises.**	1) D-12 Maintenance wrote in 2000 of the problems in maintaining the cable and keeping parts. D-12 then recommended replacing the cable with Type 5 guardrail. **Cable is still in place as no project has coincided with this work.** **Widening project is programed.**
--------- **CONCLUSIONS FROM FIELD VISITS** (Generic system not visited) ---------				
Performance Conclusions	System performing to NCHRP Report 350 standards	System performing to NCHRP Report 350 standards	System performing to NCHRP Report 350 standards	System conforms to previous crash test criteria, NCHRP Report 230
Summary	Best accident data, longest evaluation time, proven system elsewhere, extra cable, woven. System seems to be proving itself beneficial.	Construction issues, first substantial installation for product, so mfg's. installation and repair manual being written after the fact from our experiences.	Construction went smoothly and observed repair was very easy. Looks to be a good system, but the length, and thus exposure to accidents, is limited.	District says cable needs immediate attention after an accident and parts are difficult to obtain.

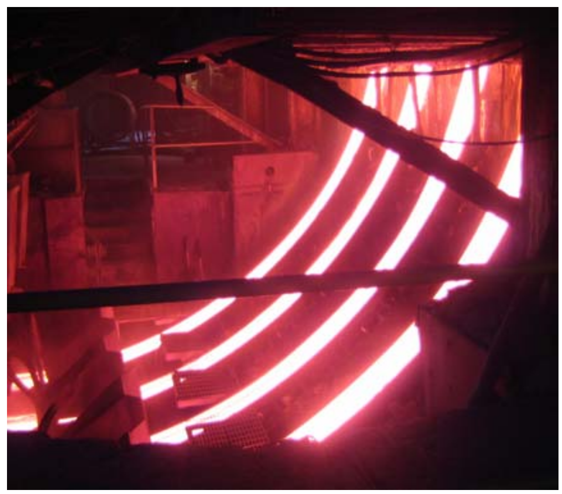
Appendix 3

Selected Photographic Material – NUCOR Marion Steel Inc. plant

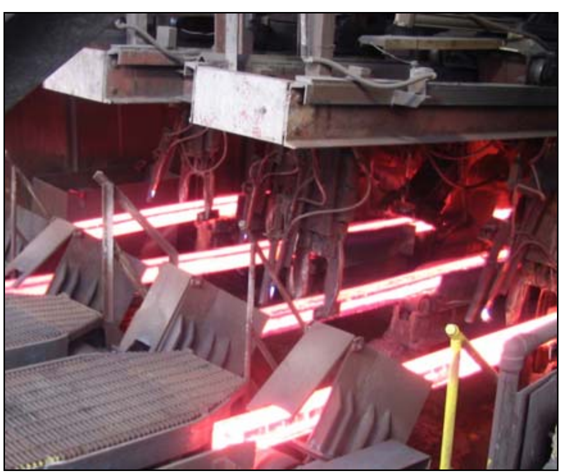
1. Melting process in electric arc furnace

2. Melt steel ready to be poured and cast

3. Steel cooled down with water.
Before casting



4. Continuous billet casting



5. Billets cut to length at the end of the line

6. Stored billets ready to be rolled

7. Posts are stored after rolling

8. Holes are punched and posts are ready to be distributed

9. U.S. High Tension Cable Installation

10. End Treatment

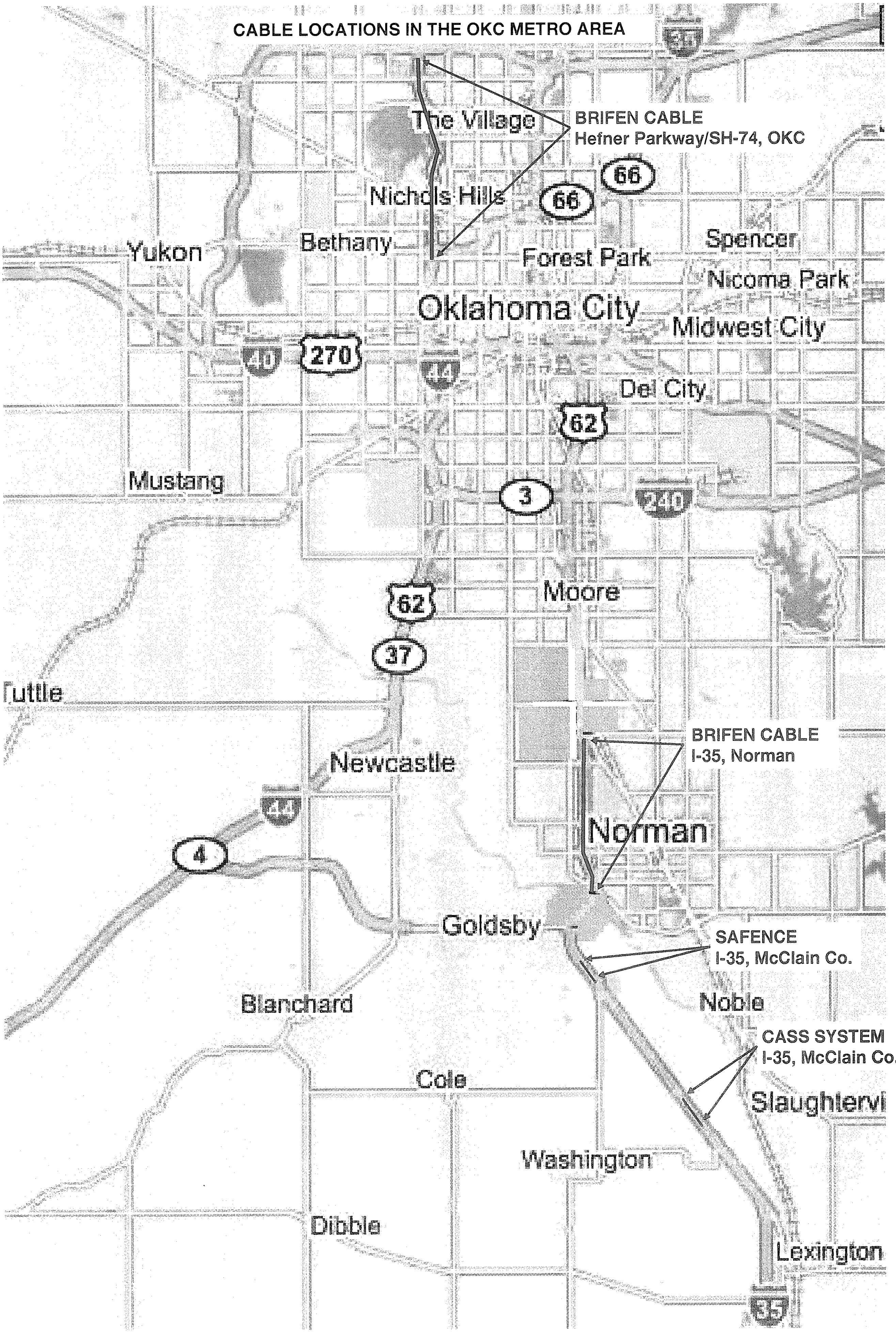
11. Anchors

12. Turnbuckle

13. Tension meter

14. U-shaped bolds to fix cable height

Appendix 4


CABLE LOCATIONS IN THE OKC METRO AREA
BRIFEN CABLE
Hefner Parkway/SH-74, OKC
BRIFEN CABLE
I-35, Norman
SAFENCE
I-35, McClain Co.
CASS SYSTEM
I-35, McClain Co.
The Village
Nichols Hills
Bethany
Yukon
Forest Park
Spencer
Nicoma Park
Oklahoma City
Midwest City
Del City
Mustang
Moore
Tuttle
Newcastle
Norman
Goldsby
Blanchard
Noble
Cole
Washington
Dibble
Lexington
35
66
270
40
44
62
3
240
37
4

Appendix 5

Cable Locations in OKC Metro Area

Traffic Engineering Division - Oklahoma Department of Transportation

Brifen - Hefner Parkway/SH-74 (Installed 9/1/01)						
Crossover Before			**Crossover After**			**Reported Barrier Hits Since Installation**
Time Frame			**Time Frame**			
9/1/96	to	8/31/01	9/1/01	to	7/31/05	
Fatal	**Injury**	**PD**	**Fatal**	**Injury**	**PD**	**Total**
6	10	4		1	1	132

Reductions	83%	90%	75%

Brifen - I-35 (Norman) (Installed 9/30/04)						
Crossover Before			**Crossover After**			**Reported Barrier Hits Since Installation**
Time Frame			**Time Frame**			
10/1/99	to	9/30/04	10/1/04	to	7/31/05	
Fatal	**Injury**	**PD**	**Fatal**	**Injury**	**PD**	**Total**
6	16	9	0	0	1	21

Reductions	100%	100%	89%

Safence - I-35 (McClain County) (Installed 9/30/04)						
Crossover Before			**Crossover After**			**Reported Barrier Hits Since Installation**
Time Frame			**Time Frame**			
10/1/99	to	9/30/04	10/1/04	to	7/31/05	
Fatal	**Injury**	**PD**	**Fatal**	**Injury**	**PD**	**Total**
1	5	1	0	0	0	3

Reductions	100%	100%	100%

Cass System - I-35 (McClain County) (Installed 8/26/05)						
Crossover Before			**Crossover After**			**Reported Barrier Hits Since Installation**
Time Frame			**Time Frame**			
8/1/0	to	7/31/05	No Data Available			
Fatal	**Injury**	**PD**	**Fatal**	**Injury**	**PD**	**Total**
3	1	3	No Data Available			No Data Available

Appendix 6

Selected Photographic Material – Oklahoma

1. Brifen Post

2. Brifen Installation on SH-74

3. Detail Brifen weaving cable

4. End treatment protected with sand barrels

5. Top view Brifen TL-3 post

6. Concrete foundation and plastic extruder

7. Turnbuckle on Brifen installation

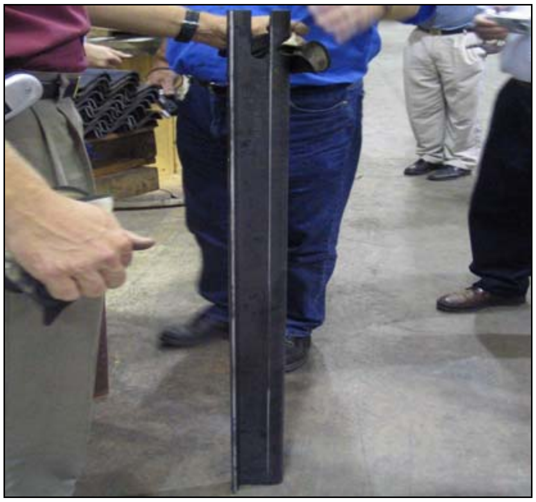
8. Brifen Turnbuckle -Detail

9. Brifen system on I-35

10. SAFENCE system on I-35

10. Reinforced socket – Brifen

11. TL-3 posts - Brifen



11. TL-3 post – Brifen

12. TL-4 post – Brifen

13. TL-3 extruder + TL-4 post + plastic cap with reflectors

Appendix 8

OKLAHOMA DEPARTMENT OF TRANSPORTATION

June 24, 2004

Oklahoma DOT Experience with
Brifen Wire Rope Safety Fence on
Lake Hefner Parkway in Oklahoma City

Almost 3 years have passed since the Brifen Wire Rope Safety Fence (WRSF) was installed on Lake Hefner Parkway in Oklahoma City, and it is appropriate to look at how it has performed. This 7-mile project was the first Brifen WRSF installed anywhere in the United States and we frequently are asked by other states and local entities what we think of its performance. Since I am involved in maintaining safety appurtenances in this metropolitan area, I have closely watched the Brifen WRSF on Lake Hefner Parkway. Some comments are:

- This 7-mile system was installed in two sections. One section is 2 miles long and the other is 5 miles in length. There is an anchor at the end of each section (4 total). There are no intermediate end anchors, which makes for a simple, straightforward installation and reduced future maintenance.
- As of May 10, 2004 the system had 238 hits, requiring replacement of 1279 posts for an average of 5.3 posts per hit. Maintenance (by contract) costs $51.00 per post replaced, for an average repair cost per hit of $270.00. This covers material, labor and traffic control. Repair of a similar length of w-beam guardrail would be far more expensive and time consuming. (3 sections of 25' rails, post, bolts, etc. plus heavy equipment)
- To our knowledge, police accident reports have only been filed on approximately 30% of the hits, meaning 70% of the vehicles received only minor damage and drivers were uninjured and able to drive away. Only 3 injuries have been reported as far as we know. A number of the hits have been at very high speed and at impact angles approaching 90°. The largest vehicle to impact the system was a full size school bus. The bus was re-directed safely after the driver had a heart attack. This is a remarkable record compared to any other type of barrier (w-beam, concrete, etc), which generally cause extensive vehicle damage when hit and injuries can be severe.
- One of the major benefits of the Brifen WRSF has been the short time required to make repairs. A typical 5-post repair is usually made in about 15 minutes by one person using only hand tools. Two people can do it even faster. This means crews are not in harms way for very long and there is little or no delay to traffic.
- The WRSF normally stays up after a hit, and has successfully re-directed additional nearby hits prior to being repaired. It does not fall to the ground after a hit like the 3-cable systems are known to do, which would leave a gap in the protection. We have had only a few cases, when many posts were knocked out, that the cables have dropped down to the ground. In those cases repairs were made within 2 hours as required by the contract for those type hits.
- In an effort to reduce costs for vegetation control, an asphalt "mowing strip" was placed under the WRSF for the full length of the project. It is 4 feet wide and 4" thick and placed adjacent to the southbound lanes. The WRSF is centered in this strip. This adds cost and is not very effective since grass has now over grown much of the strip and hand mowing is still needed. Use of a soil sterilant herbicide may be more cost-effective.

In summary, our experience with Brifen WRSF has been excellent. We have had no fatalities and only 3 barrier-involved injuries to date as far as we know. It is a highly cost effective barrier that has served the traveling public extremely well. In fact, the Lake Hefner Parkway Brifen WRSF won a prestigious Federal Highway Administration National Safety Award in November 2003 in competition with many safety projects from all around the country.

We hope to continue its use on other sites as funding becomes available. We do not support using other unproven cable barrier systems when we already have a system that we know saves lives and property damage, and is easy and inexpensive to repair. A side benefit is that Brifen WRSF is manufactured right here in Oklahoma City, providing needed jobs for local workers.

Randy B. Lee

Randy B. Lee, P.E.
Division IV Traffic Engineer

Appendix 9

QUESTIONS FOR ASAP TOUR FOR MEDIAN CROSSOVER CRASH COUNTERMEASURES

Scoping

When is placement of a median barrier considered?
- New Construction? **Yes**
- Reconstruction? **Yes**
- Resurfacing/Restoration/Rehabilitation (3R)?
- Response to crash history? (Project initiated to address safety concern) **Yes**
- Systemwide policy to implement barrier?
- Political?
- Other?

Warrants

How does the agency decide when a median barrier is warranted?
- Cross section, traffic, alignment, etc?
- Crash history? **Yes**
- Across the board policy?
- Case-by-case? **Yes**

How does the agency decide when a high tension cable median barrier should be used, rather than some other system [e.g., cost, deflection, median width, maintenance, design vehicle, terrain, aesthetics, snow plowing, soil conditions, other]?

- **Cost**
- **Deflection**
- **Median Width**
- **Maintenance**
- **Aesthetics**

QUESTIONS FOR ASAP TOUR FOR MEDIAN CROSSOVER CRASH COUNTERMEASURES

Design

What is the status of high tension cable barrier in your Agency? **We are evaluating the different kinds.**

What high tension cable median barrier systems do you allow? **Brifen, Safence, Cass (under evaluation)**

What are the differences that affect your choice of systems?

What is the maximum typical slope on which you place the barrier? **6:1**

What guidelines do you use for coordination of the barrier and median slopes?

What location(s) do you use for placement of the barrier, along shoulder, near center of median, intermediate? Describe. **We have placed it along the shoulder, near center and are evaluating it.**

Do you place a mow strip under the barrier?
    Under what conditions?
    What material? Width? Thickness?

We placed mow strip under the Barrier for two (2) projects and did not for two (2) and are evaluating it.

Have you made any special designs due to frost heave concerns? **No**

Have you made any special designs due to soil conditions? **No**

How do you accommodate median crossovers? Are you eliminating crossovers? **No**

How do you accommodate mainline bridges? **We go along on side of bridge.**

How do you coordinate with other safety barriers and/or impact attenuators? **With concrete barriers we place it behind it, place it between impact attenuators.**

How do you coordinate with existing fixed objects, such as bridge piers , inlets, sign bridges? **We go along one side of it and keep the protection for the fixed objects.**

What other safety treatments do you apply in conjunction with the barrier?
    Shoulder rumble strips? **No**
    Delineators? **Yes**
    Other?

Have you used socketed posts? **Yes**

Have you used driven posts/sockets? **No**

Do you place the high tension cable median barrier only in freeway medians? **Yes**
    What other locations? **None**

QUESTIONS FOR ASAP TOUR FOR MEDIAN CROSSOVER CRASH COUNTERMEASURES

What is the longest run of cable between anchors? **5 miles**

Design requirements for curves and tapers, e.g. post spacing, minimum and maximum criteria?

How are posts in rock detailed? **Not encountered**

Design (continued)

Is estimated deflection for a given post spacing based on the manufacturer's recommended design? If not, explain. **Yes**

Do you consider 3-cable and 4-cable systems to be equivalent? **We are experimenting with both 3-cable and 4-cable systems.**

Have you or do you plan to use TL4 cable guard? What criteria do you use? **?**

QUESTIONS FOR ASAP TOUR FOR MEDIAN CROSSOVER CRASH COUNTERMEASURES

Installation

What production rate is typical [for both L.F. of cable guard and terminal installation]? [Does it vary by location (mid-median vs. edge of shoulder)? Does it vary by product?]

Were there any problems with construction of the mow strip (if used)?

Describe any difficulties with installation of the cable barrier.

Have you experienced any problems with installations in rock?

How much time is required between concrete post installation and tensioning?

Have you experienced any quality problems with manufactured materials?

Have you experienced any quality problems with constructed materials, e.g. concrete?

Do you use each manufacturer's recommended tension meter for installation? Do you have a preference?

QUESTIONS FOR ASAP TOUR FOR MEDIAN CROSSOVER CRASH COUNTERMEASURES

Performance

Has the system allowed any "design" vehicles to penetrate?
If so, why?

Has the system caused any rollovers or other severe consequences?
What factors contributed? No

Has the system remained serviceable between the time of an initial impact and start of repairs? Yes

Has the system contained any vehicles beyond the "design" limitations (speed or mass)?

Has observed deflection matched design deflection? Yes

Have you observed any cracking, spalling, break-offs, etc in the concrete posts as a result of impact? Weather? No

Have wet medians, poor soils, and/or frost resulted in barrier shifting or jacking up? If so, has this affected performance? No

Is the system cost effective (in terms of reducing crash/improving safety vs the amount of money spent)? Yes

QUESTIONS FOR ASAP TOUR FOR MEDIAN CROSSOVER CRASH COUNTERMEASURES

Maintenance

Have the system anchors remained stable? Yes

Who does the repairs? (State forces, or contract forces) Both for Brifen (Contractor) & Safence (State forces)

How is training handled? Contractor (supplier trains – part of contract). Reqire Contractor to have certified training.

How difficult have repairs been? Simple

Have repair parts been readily available? How much time is required for delivery? Yes. For Brifen - insignificant.

Have repairs caused any confusion regarding parts or methods? No

Have winter repairs caused any special problems (posts frozen in sockets, etc.) No

Has tension been checked after repairs? Yes, at first periodically. It has been ok to check less now.

Does the cable hold correct tension after an impact? Yes

Does the system cause complications for mowing? For snow plowing? Yes. For snow plowing no problem.

Does the system cause complications for other maintenance activities? No

Does the system cause complications for emergency responders and police? Were special training or informational sessions offered? We were concerned but we have not had any problems.

How much time is spent on-site for the average repair? Is more time needed in the winter? Avg. 20 Minutes, same for winter.

Have any repairs required cable replacement? No Have any repairs required replacement of concrete posts or anchors? No

What parts are required for the typical repair? Just the posts and some of the caps

Do you keep an inventory of parts on hand? No – contractor does.
Do you keep cable on hand? How do you estimate the inventory of parts to keep on hand? Where are they stored? What parts are stored inside? What parts are stored outside? It is not an issue for us.

Does maintenance prefer a mid-median or shoulder location? Mid Median, we prefer it to be off set from the center of the median.

QUESTIONS FOR ASAP TOUR FOR MEDIAN CROSSOVER CRASH COUNTERMEASURES

Maintenance (continued)

Has maintenance observed any frost heave? If so, how have they handled it? No

Has maintenance observed any salt damage? No

Does cable hold tension over time? Yes

How many tension meters and other specialized tools does each maintenance unit have? None, contractor has one.

How do maintenance workers feel about having to maintain the system with greater exposure to Interstate traffic? Contractor does it for Brifen.

How does law enforcement feel about not being able to go through the ditches to catch speeders going in the other direction? We have not had any complaints.

Appendix 10

SPECIAL SPECIFICATION
5084
Cable Barrier System

1. **Description.** Furnish and install a cable barrier system and cable barrier terminal sections at the locations shown on the plans.

2. **Materials.** Furnish a new cable barrier system and cable barrier terminal sections in accordance with the details shown on the plans and on the manufacturer's shop drawings, or equal as approved.

   Furnish Class C concrete in accordance with Item 421, "Hydraulic Cement Concrete."

   Furnish delineators as shown on the plans and in accordance with Item 658, "Delineator and Object Marker Assemblies."

3. **Construction.** Install cable barrier system and cable barrier terminal sections in accordance with the details shown on the plans and manufacturer recommendations. Place posts into steel sleeves in a concrete foundation, unless otherwise shown on the plans. Locate terminal sections at locations as shown on the plans. Repair or replace damaged parts immediately. Provide the Engineer with an installation and repair manual specific to the cable barrier system and cable barrier terminal sections.

4. **Measurement.** This Item will be measured by the foot of cable barrier system and by the each cable barrier terminal section installed.

5. **Payment.** The work performed and the materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Cable Barrier System" and "Cable Barrier Terminal Section." This price is full compensation for furnishing cable barrier system, cable barrier terminal section, concrete, delineators, equipment, labor, tools, and incidentals.

   Shielding of end anchor sections if needed will be paid for under other Items.

   Delineators will not be measured or paid for directly, but will be considered subsidiary to this Item.

Appendix 11

Selected Photographic Material – Texas

1. CASS Post on I-20

2. CASS Installation on I-20

3. Detail CASS post

4. CASS Turnbuckle

5. TTI's end treatment post on CASS

6. TTI's anchor post – Top view

7. TTI's anchors

8. Inappropriate turnbuckle placement

9. Trailer for carrying repair parts

10. Trailer compartments

11. Brifen installation on I-20

12. Brifen anchor system

Appendix 12

PARKER STP2005(792)SFT

FED. ROAD DIV. NO.	STATE	FEDERAL AID PROJECT NO.	SHEET NO.
6	TEXAS	STP2005(792)SFT	1
STATE DISTRICT	COUNTY	STATE CONTROL NO.	HIGHWAY NO.
FTW	PARKER	0314-07-032	IH 20

STATE OF TEXAS
DEPARTMENT OF TRANSPORTATION

PLANS OF PROPOSED
STATE HIGHWAY IMPROVEMENT

FEDERAL AID PROJECT STP 2005(792)SFT
PARKER COUNTY
IH 20

FROM: SP 312
TO: FM 1884

FOR THE CONSTRUCTION OF INSTALLING MEDIAN BARRIER

NET LENGTH = 25,417 FT = 4.8 MI

INDEX OF SHEETS

Δ REVISED 6.28.2005

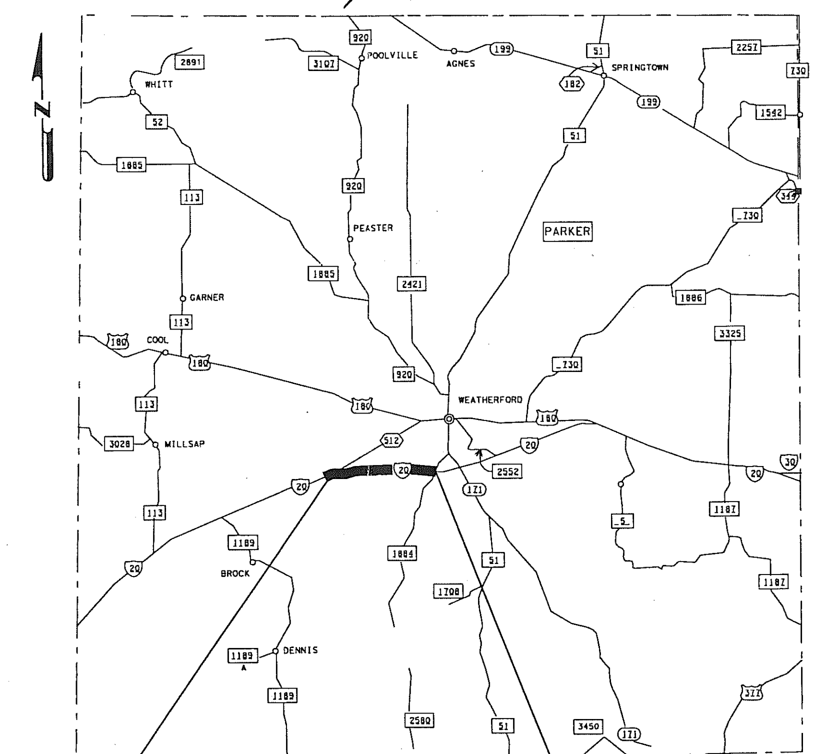
LETTING DATE: ____________

DATE WORK BEGAN: ____________

DATE WORK COMPLETED: ____________

DATE WORK ACCEPTED: ____________

CONTRACTOR: ____________



BEGIN PROJECT
STA 1983 + 09.10
REF MKR = 402 + 0.283

END PROJECT
STA 2237+26.50
REF MKR = 407+0.097 MI

NO RAILROADS
NO EXCEPTION
NO EQUATIONS

STATE OF TEXAS
JIMMEY F. BODIFORD
74250
REGISTERED
PROFESSIONAL ENGINEER

Jimmey F. Bodiford, P.E.
3-23-05

TEXAS DEPARTMENT OF TRANSPORTATION

SUBMITTED FOR LETTING: 3-23-05
Jimmey F. Bodiford, P.E.
AREA ENGINEER

RECOMMEND FOR LETTING: 3/29/05
[signature], P.E.
DISTRICT ENGINEER

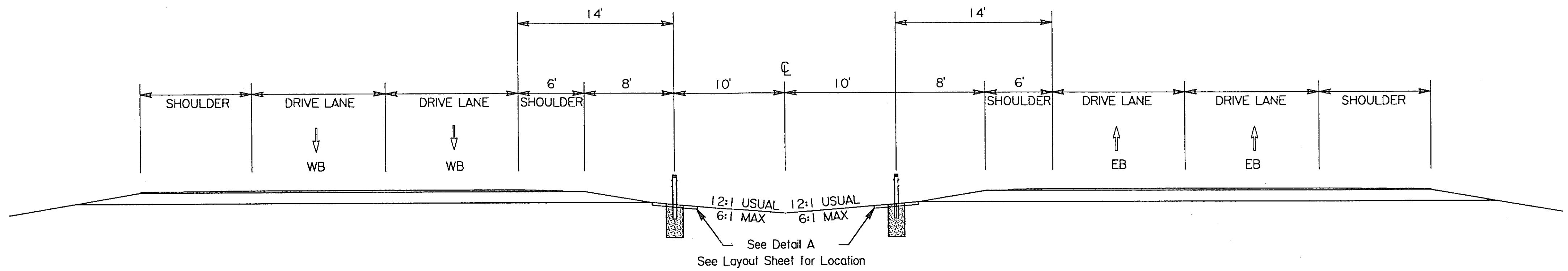
APPROVED FOR LETTING: ____________
DIRECTOR, TRAFFIC OPERATIONS DIVISION

APPROVED FOR LETTING: ____________
DIRECTOR OF BRIDGE DIVISION

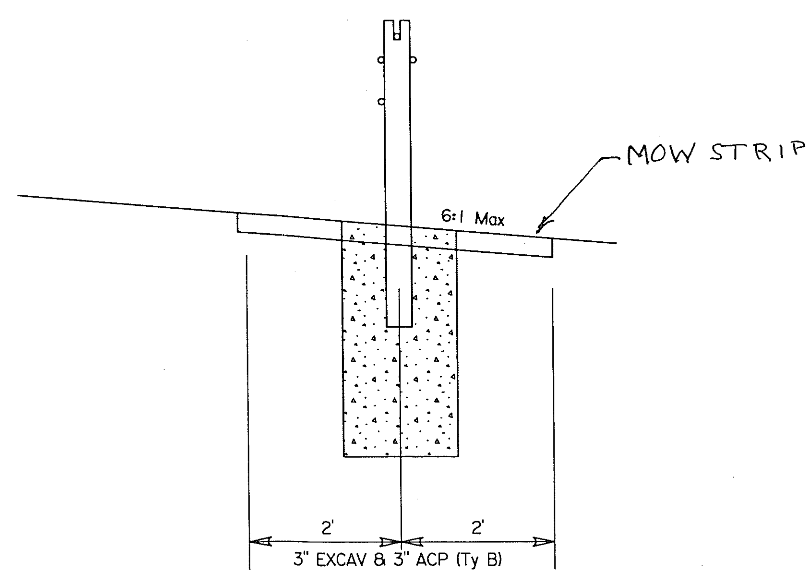
APPROVED FOR LETTING: 05.26.05
Maria [signature], P.E.
FOR DIRECTOR OF DESIGN DIVISION

* — STANDARD SHEETS SPECIFICALLY IDENTIFIED ABOVE HAVE BEEN SELECTED BY ME OR UNDER MY RESPONSIBLE SUPERVISION AS BEING APPLICABLE TO THIS PROJECT.

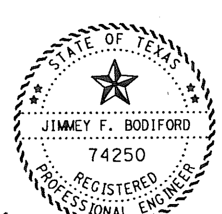
NOTE: SPECIFICATIONS ADOPTED BY THE TEXAS DEPARTMENT OF TRANSPORTATION, JUNE 1, 2004 AND SPECIFICATIONS ITEMS LISTED AND DATED AS FOLLOWS, SHALL GOVERN ON THIS PROJECT: REQUIRED CONTRACT PROVISIONS FOR ALL FEDERAL-AID CONSTRUCTION CONTRACTS (FORM FHWA 1273, DECEMBER, 1993)



TYPICAL SECTION



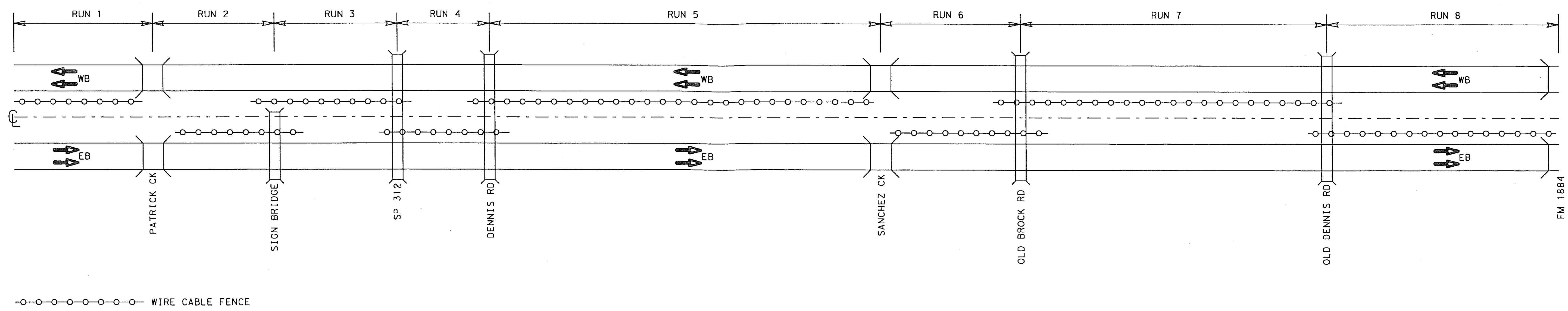
Detail A



Jimmey F. Bodiford, P.E.
3-23-05

TYPICAL SECTIONS

FED. RD. DIV. NO.	FEDERAL AID PROJECT NO.		SHEET NO.
6			2
STATE	STATE DIST. NO.	COUNTY	
TEXAS	FTW	PARKER	
CONT.	SECT.	JOB	HIGHWAY NO.
0314	07	032	IH 20



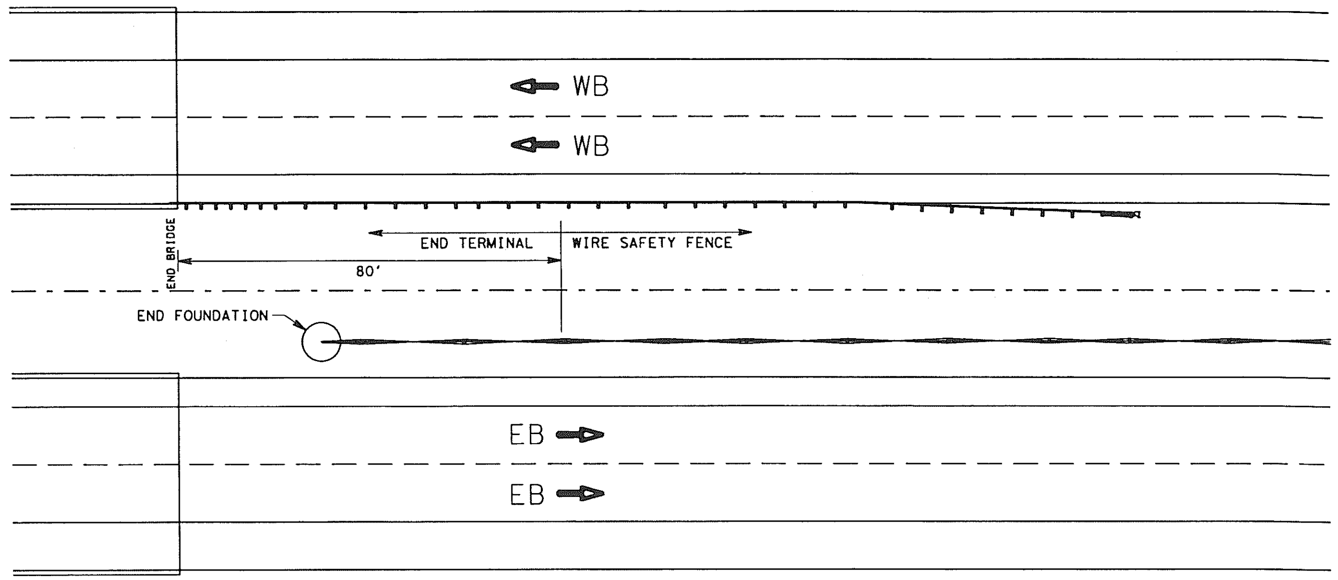
RUN NO.	FROM	TO	EXCAVATION (CY)	SEEDING (SY)	VEG WATER (MG)	ACP (TY B) (TON)	WIRE ROPE/CABLE (LF)	TERMINAL SECT (EA)
1	BEGIN PROJECT	PATRICK CREEK	109	1301	27.4	215	2827	2
2	PATRICK CREEK	SIGN BRIDGE	64	765	16.1	127	1620	2
3	SIGN BRIDGE	SP 312	119	1420	29.9	235	3093	2
4	SP 312	DENNIS RD	66	791	16.7	131	1679	2
5	DENNIS RD	SANCHEZ CREEK	278	3328	70.0	550	7388	2
6	SANCHEZ CREEK	OLD BROCK RD	99	1184	24.9	196	2562	2
7	OLD BROCK RD	OLD DENNIS RD	228	2735	57.5	452	6053	2
8	OLD DENNIS RD	FM 1884	173	2073	43.6	342	4563	2
		SHEET TOTALS	1136	13597	286.1	2248	29785	16

STATE OF TEXAS
JIMMEY F. BODIFORD
74250
REGISTERED
PROFESSIONAL ENGINEER

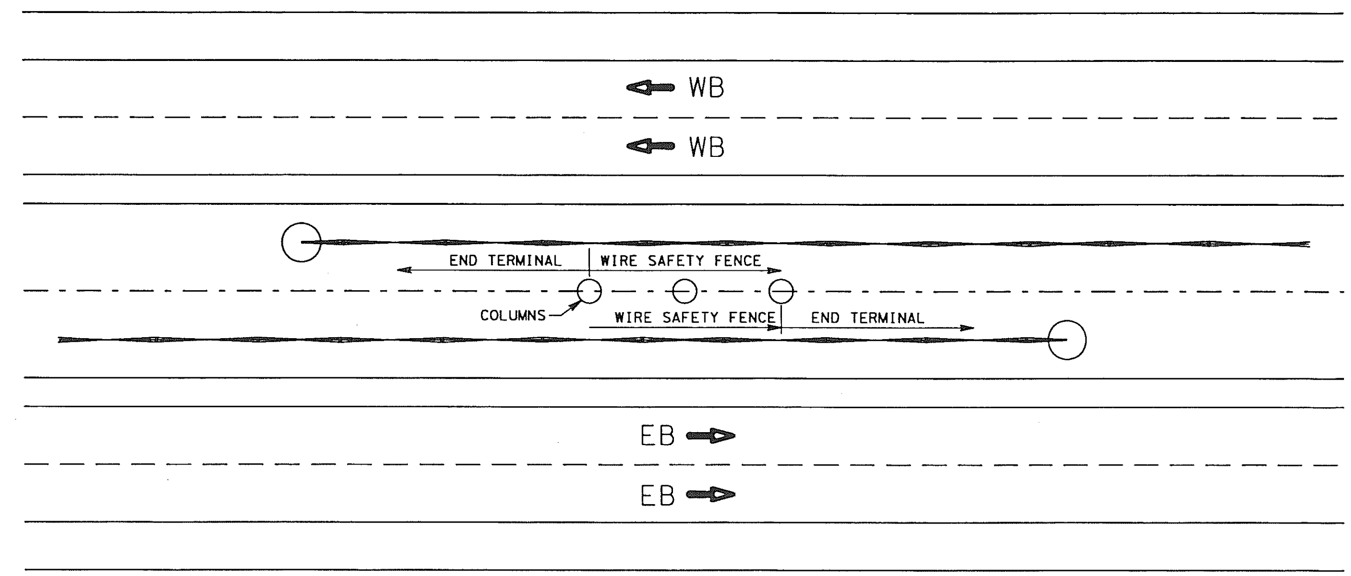
Jimmey F. Bodiford, P.E.
3-23-05

PROJECT LAYOUT

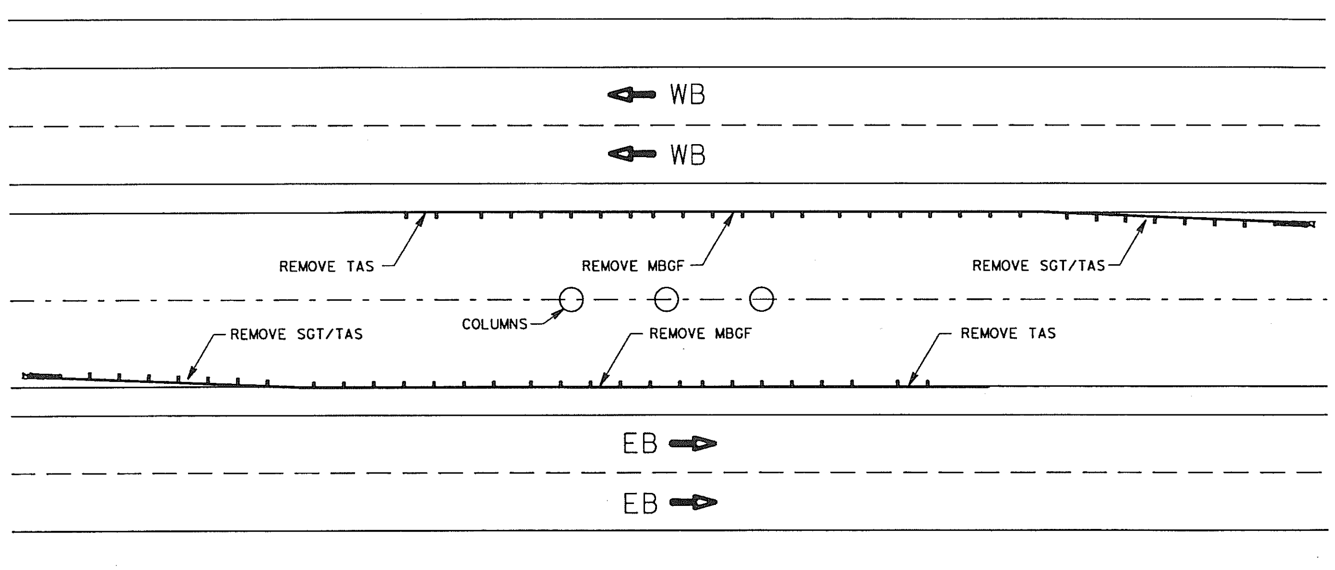
FED. RD. DIV. NO.	FEDERAL AID PROJECT NO.			SHEET NO.
6				19
STATE	STATE DIST. NO.	COUNTY		
TEXAS	FTW	PARKER		
CONT.	SECT.	JOB	HIGHWAY NO.	
0314	07	032	IH 20	



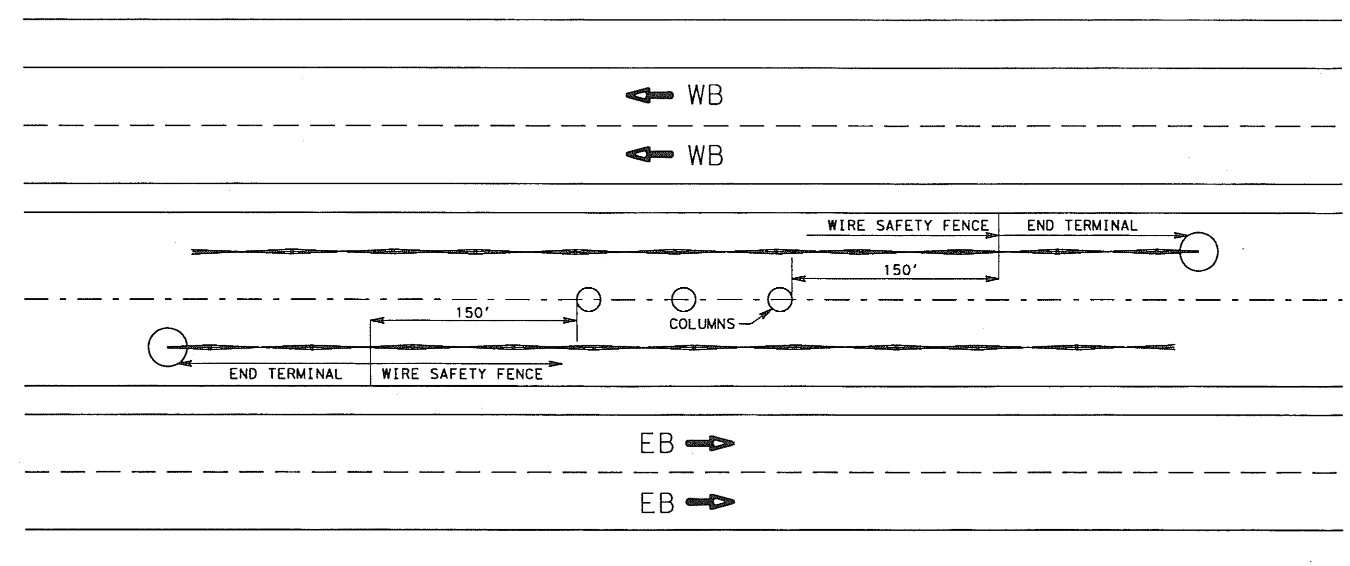
TYPICAL PLACEMENT AT BRIDGE END DETAIL



TYPICAL PLACEMENT AT BRIDGE COLUMNS - DETAIL 1



TYPICAL REMOVAL DETAIL



TYPICAL PLACEMENT AT BRIDGE COLUMNS - DETAIL 2

LOCATION	REMOVE TAS (EA)	REMOVE MBGF (LF)	REMOVE GET (EA)
SIGN BRIDGE	2	250	2
SP 312	2	350	2
DENNIS RD	2	250	2
OLD BROCK RD	2	250	2
OLD DENNIS RD	2	250	2
PROJECT TOTALS	10	1350	10

STATE OF TEXAS
JIMMEY F. BODIFORD
74250
REGISTERED
PROFESSIONAL ENGINEER

Jimmey F. Bodiford, P.E.
3-23-05

ROADWAY DETAILS

FED. RD. DIV. NO.	FEDERAL AID PROJECT NO.		SHEET NO.
6			20
STATE	STATE DIST. NO.	COUNTY	
TEXAS	FTW	PARKER	
CONT.	SECT.	JOB	HIGHWAY NO.
0314	07	032	IH 20

LEVELS DISPLAYED

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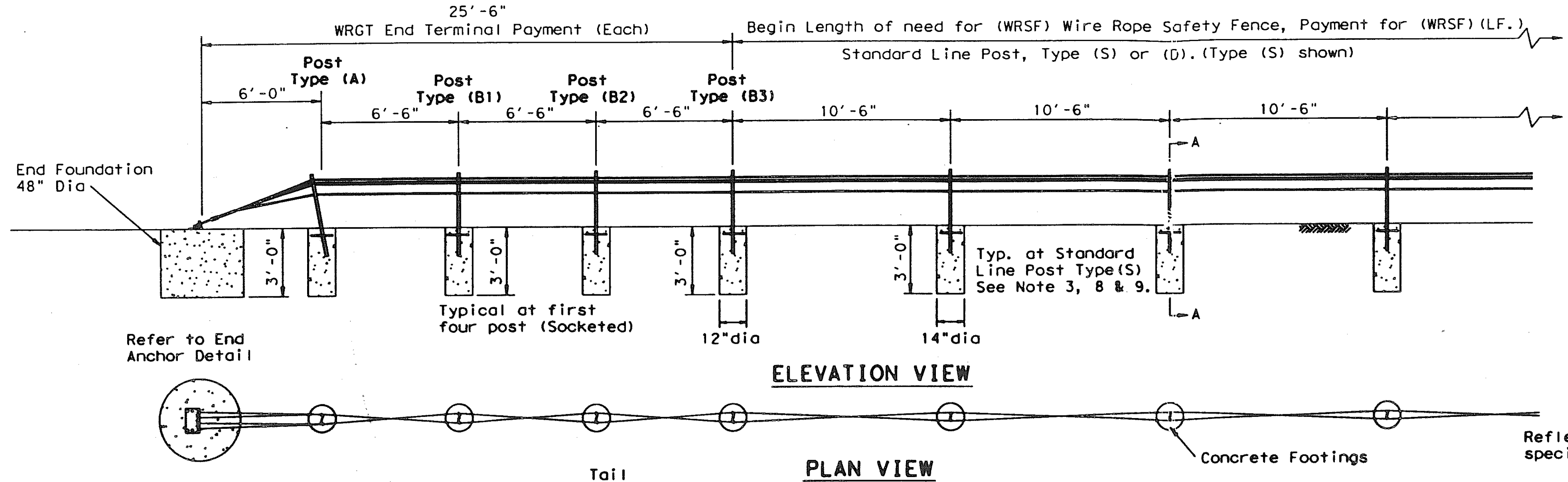
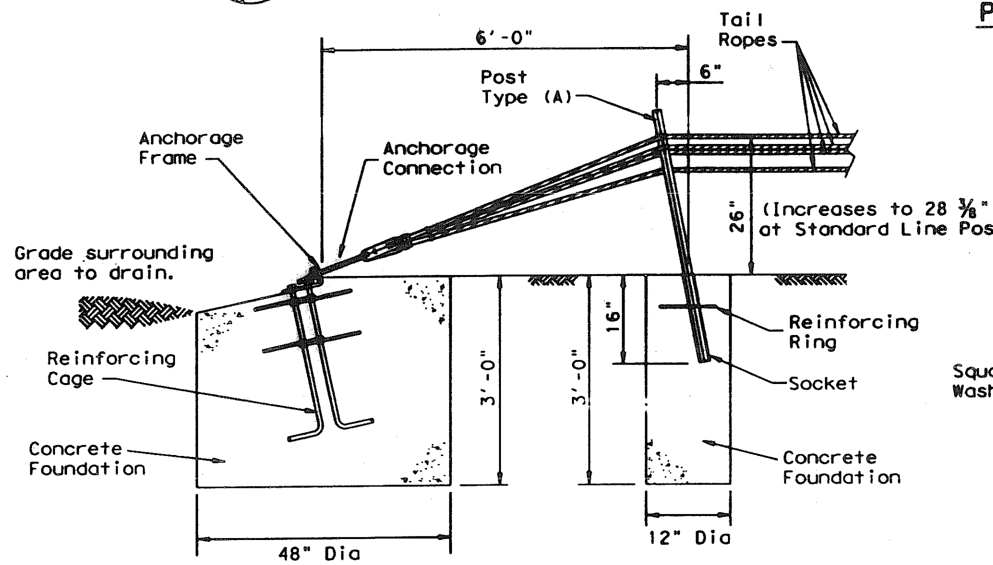
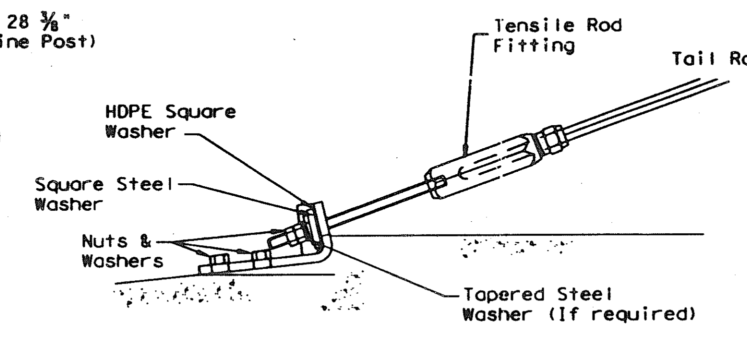
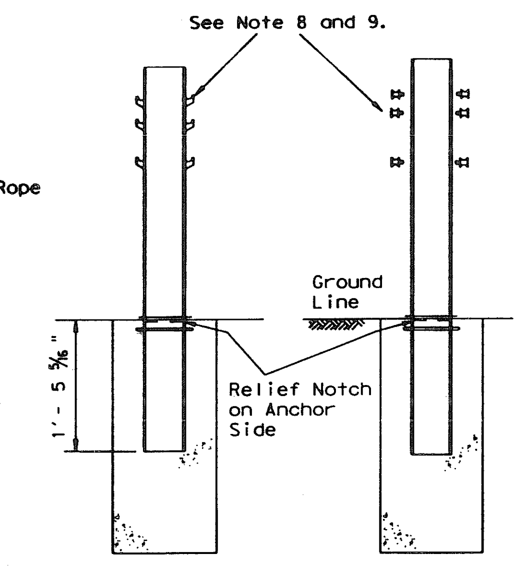




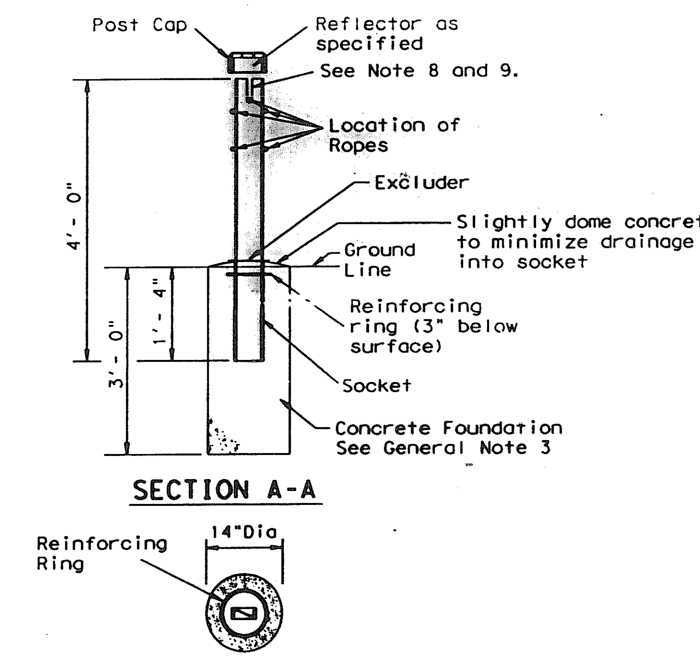
END ANCHORAGE DETAIL



ANCHORAGE CONNECTION DETAIL



WRGT TERMINAL POSTS DETAIL

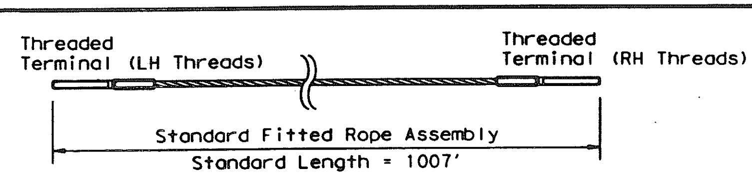


STANDARD LINE POST CONCRETE FOUNDATION (SOCKET)

SOCKETED POST (TYPE S) DETAIL

GENERAL NOTES

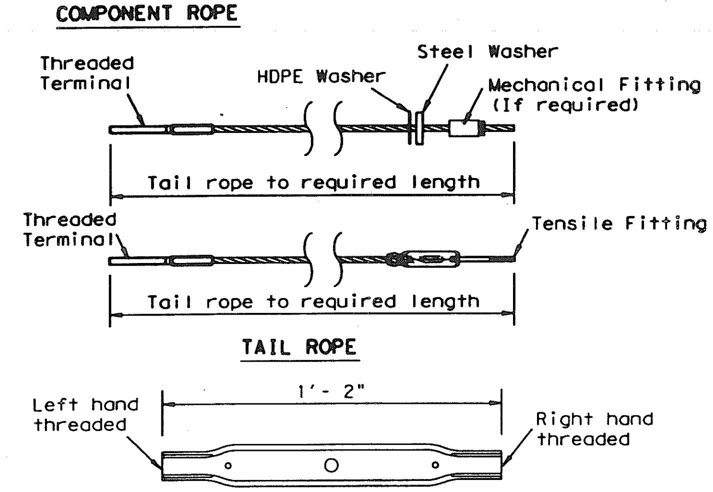
1. WRGT End Terminal meets NCHRP-350 TL-3.
2. No limit to length between end terminals.
3. All posts are set in concrete sockets unless otherwise specified.
4. Spacing of the line post may be decreased. For additional information see the manufacturer's product manual.
5. End Terminal is NCHRP-350 approved and may be located within the Horizontal Clear Zone. End Terminal may not exceed 25:1, 50:1 or less is preferred.
6. Wire Rope Safety Fence (WRSF) is recommended for installations on slopes of 6:1 or flatter, placed where an errant vehicle can approach on a relatively smooth surface.
7. WRSF may be installed on either side of the roadway. The radius edge of posts shall be on the approach side of traffic. Line post shall be socketed design unless otherwise specified.
8. First 15 line posts adjacent to WRGT End Terminal. Terminal Post do not have top rope slot. The top rope weaves on either side of posts until the first line post with a slot.
9. All posts are made so that ropes may be placed on either side of post depending on rope weave pattern.
10. For additional information, contact Brifen USA Inc. at 1-800-427-4336.



COMPONENT ROPE

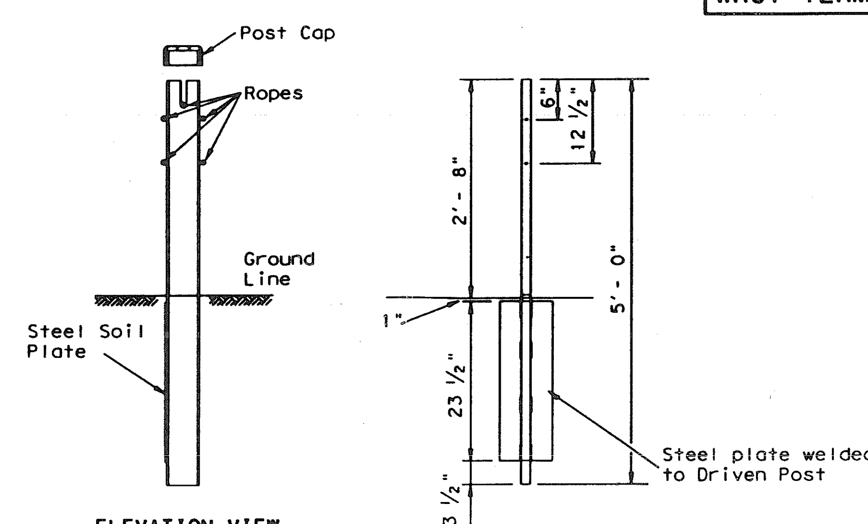
TENSION CHART

AMBIENT TEMPERATURE	ROPE TENSION
F	LBS
100	2110
95	2531
86	3150
77	3769
68	4387
59	5006
50	5625
41	6244
32	6863
23	7481
14	8100
0	9100



TURNBUCKLE/RIGGING SCREW [A52]

ROPE COMPONENTS AND TENSION CHART



(OPTIONAL) LINE POST
See General Note 3

DRIVEN POST (TYPE D) DETAIL

STATE OF TEXAS
JERRY W. EMERSON
28220
REGISTERED PROFESSIONAL ENGINEER
2/26/05

WIRE ROPE SAFETY FENCE
(Brifen USA, Safety Fence)

FED. RD. DIV. NO.	FEDERAL AID PROJECT NO.			SHEET NO.
6				21
STATE	STATE DIST. NO.	COUNTY		
TEXAS	FTW	PARKER		
CONT.	SECT.	JOB	HIGHWAY NO.	
0314	07	032	IH 20	

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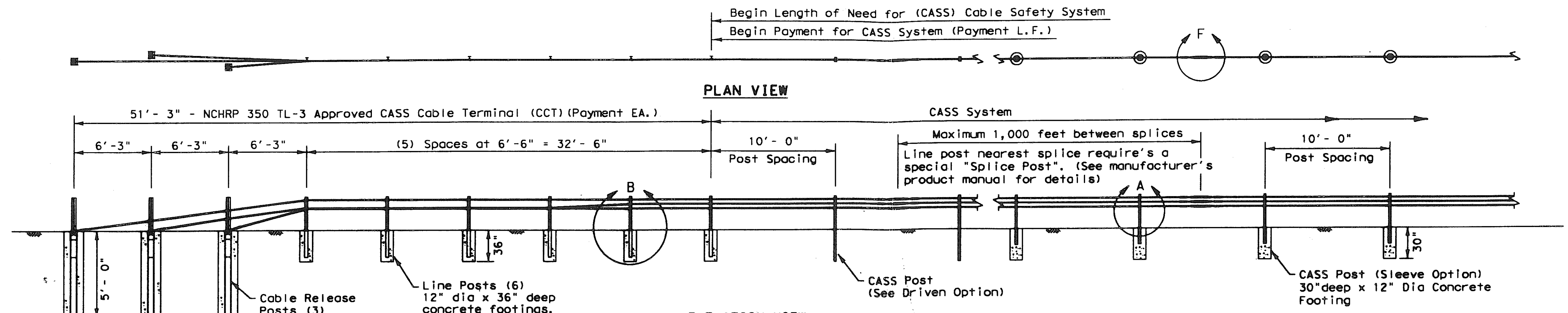

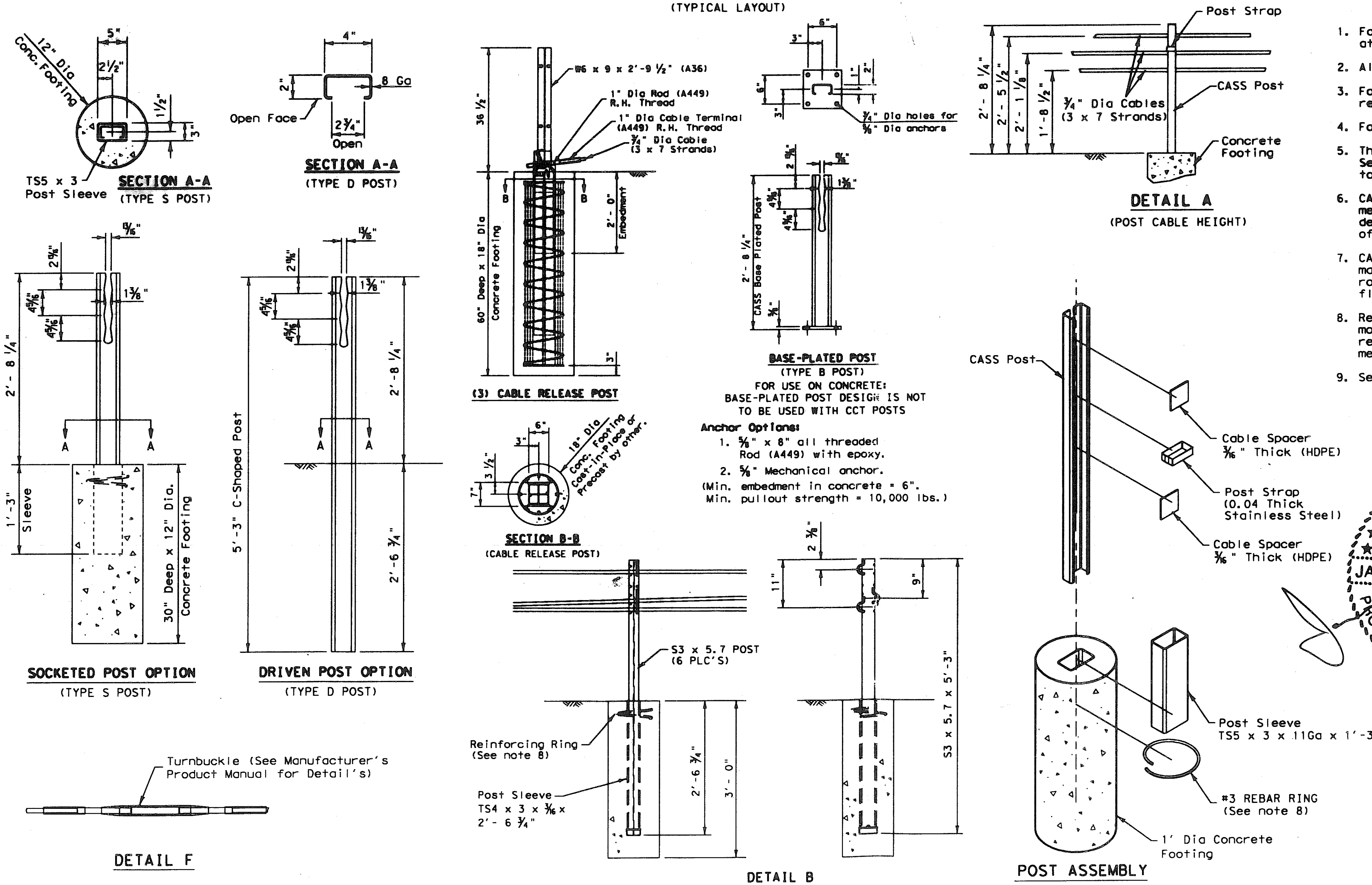

GENERAL NOTES

1. For additional information, contact Trinity Industries, Inc. at 1-800-527-6050.
2. All concrete shall be class C.
3. For cable barrier installation lengths and terminal cable (CCT) requirements. (See the manufacturer's product manual)
4. For payment see special specification "Cable Barrier System".
5. The CASS system is designed for bi-directional traffic flows. See the manufacturer's product manual for placement adjacent to guardrail end treatments.
6. CASS shall be installed on median shoulders or in depressed medians with slopes of 6:1 or flatter without obstructions, depressions, etc. that may significantly affect the stability of an errant vehicle.
7. CASS may be installed on either side of the median. CASS post may be socketed or driven design and shall be alternately rotated 180 degrees so that every other post is facing traffic flow.
8. Rebar ring is not required if installed in a 3 ft. (min.) width mow strip of 8 in. (min.) asphalt depth or 4 in. (min.) reinforced concrete depth. If minimum requirements are not met contact Trinity Industries to discuss footings.
9. See the Texas MUTCD for proper delineation.

CABLE TENSION CHART	
F	lbf
-11	7329
0	6969
10	6609
21	6250
32	5912
43	5553
54	5193
64	4833
79	4361
93	3867
104	3530

STATE OF TEXAS
JAMES R. ALBRITTON
79261
REGISTERED PROFESSIONAL ENGINEER
6/20/05

CABLE SAFETY SYSTEM

(Trinity Industries Inc.)

FILE:	DN:	CK:	DW:	CK:
REVISIONS	DISTRICT	FEDERAL AID PROJECT		SHEET
△ REVISED 6-28-05	FTW			22
	COUNTY	CONTROL / SECT / JOB		HIGHWAY
	PARKER	0314 / 07 / 032		IH20

LEVELS ...D

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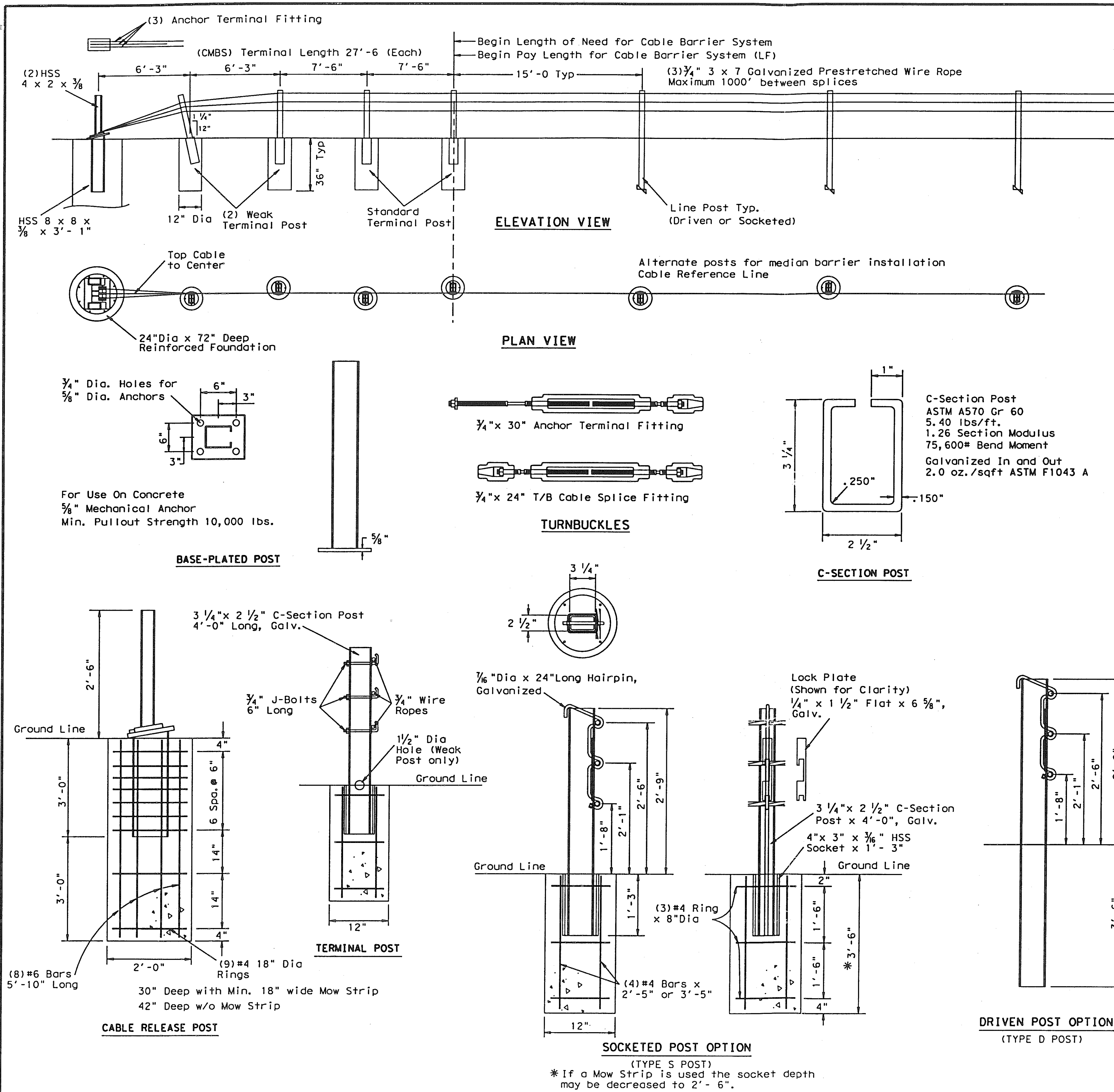

GENERAL NOTES

1. For additional information, contact Gibaltar, Inc. at 1-800-495-8957.
2. All concrete shall be class C.
3. For additional information: See the manufacturer's product manual.
4. For payment see special specification "Cable Barrier System".
5. The GCBS system is designed for bi-directional traffic flows. See the manufacturer's product manual for placement adjacent to guardrail end treatments.
6. GCBS shall be installed on median shoulders or in depressed medians with slopes of 6:1 or flatter without obstructions, depressions, etc. that may significantly affect the stability of an errant vehicle.
7. GCBS may be installed on either side of the median. Post may be socketed or driven design.
8. See the Texas MUTCD for proper delineation.

CABLE TENSION CHART	
F	lbf
-10	8210
0	7819
10	7447
20	7069
30	6677
40	6301
50	5928
60	5536
70	5155
80	4773
90	4390
100	4009
110	3627

STATE OF TEXAS
AURORA MEZA
66201
REGISTERED
PROFESSIONAL ENGINEER

Aurora Meza, P.E.
6/27/05

GIBRALTAR CABLE BARRIER SYSTEM

(Gibraltar Inc.)

ΔADDED 6·28·05

FILE:	DN:	CK:	DW:	CK:
REVISIONS	DISTRICT	FEDERAL AID PROJECT		SHEET
	FTW			22A
	COUNTY	CONTROL SECT	JOB	HIGHWAY
	PARKER	0314 07	032	IH 20

Appendix 13

MAINTENANCE / REPAIR LOG
Wire Cable Median Barrier Systems

ACCIDENT #6 INFORMATION

DATE: 7/12/2005 ***LIGHT CONDITION:*** NIGHT

TIME: UNKNOWN ***ROAD CONDITION:*** DRY

HIGHWAY: IH 20 ***APPROX. REFERENCE MARKER:*** *MM 419*

DIRECTION OF TRAVEL: $\boxed{\text{EAST}}$ WEST

VEHICLE TYPE: $\boxed{\text{CAR}}$ TRUCK SEMI UNKNOWN

PROPERTY DAMAGE ONLY: YES NO ***NUMBER OF INJURIES:*** N/A

(No Injuries/Fatalities) ***NUMBER OF FATALITIES:*** N/A

PREVENT CROSSOVER: $\boxed{\text{YES}}$ NO

BRIEF DESCRIPTION OF INCIDENT:

DPS CALLED IN DAMAGED TO WIRE ROPE BARRIER. VEHICILE WAS EVADING ARREST.

REFER TO # 7, 9 & 10 PIC'S

REPAIR INFORMATION

DATE: 7/12/2005

TIME: 8:30 AM

PRODUCT: $\boxed{\text{BRIFEN}}$ TRINITY ***# OF EMPLOYEES:*** 2

 # OF HOURS: 6

 # OF POSTS REPLACED: 27 ***MATERIAL COST:***

LABOR COST:

ENDTREATMENT INVOLVED: YES $\boxed{\text{NO}}$